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# CHAPTER 3

# The Current State of Cambodia's STEM Education: A Case Study of the Preah Sisowath New Generation School

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# Abstract

As a fast-growing economy with a low-skilled base, increasing Cambodia's human resources and job availability in the science, technology, engineering and mathematics (STEM) sectors will be instrumental in promoting long-term, sustainable growth. Given the importance of STEM education in Cambodia where jobs in these sectors have become increasingly available, it is essential to establish an effective STEM model that can address the sectoral skills mismatch.

As a case study, this paper will specifically examine the curriculum at the New Generation School located at Preah Sisowath High School, one of the most prominent Cambodian STEM models in the country. Four indicators have been determined to measure the effectiveness of the STEM model. They are, goals and objectives of the school, student interest, student literacy, and gender balance in STEM education. The results show that NGS has excelled as a national STEM model, weighted against these indicators. While challenges to their implementation have also been identified regarding the financial constraints, quality teacher recruitment, and the difficulty in application of new teaching pedagogy, this paper sets forth key recommendations to enable the NGS model to be expanded on a larger scale.

**Keywords:** New Generational School, STEM education, challenges in STEM education, STEM interest, STEM literacy

# Abbreviations

| | |
|---|---|
| **ADB** | Asia Development Bank |
| **KAPE** | Kampuchea Action for Primary Education |
| **ICT** | Information and Communication Technologies |
| **IOT** | Internet of Things |
| **NGS** | New Generation School |
| **MOEYS** | Ministry of Education Youth and Sport |
| **NGS SSW** | New Generation School Preah Sisowath High school |
| **PBL** | Project Based Learning |
| **STEM** | Science Technology Engineering and Mathematics |

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# Introduction

As one of the world's fastest growing economies, Cambodia, in the last 20 years, has maintained an average growth rate of 7.7% and in 2016, managed to graduate from being a least developed country to a lower-middle-income country (World Bank, 2019). With prosperous development, the Cambodian government has set goals for 2030 and 2050 to become upper-middle and finally high-income, respectively (Royal Government of Cambodia, 2013). This vision may be overly optimistic given Cambodia's current economic situation. Economic drivers are mainly in low wage and labor-intensive areas such as agriculture and garment exports, construction, and tourism. Industry and services are the two leading sectors responsible for the most robust growth, contributing 32% and 41% to GDP in 2012, respectively (OECD, 2013). Cambodia's economic drivers are weak and vulnerable (Senghor, 2015). The country depends too heavily on the low skilled and labor-intensive sectors with little room for a high-skilled workforce which in turn could add more value to the current figures. The workforce lacks a sufficient number of ICT and STEM-related professions. More importantly, a study by the International Labour Organization (2016) suggests that half of the employment positions in Cambodia, largely in low-skilled manufacturing, are at high risk of automation over the next decade or two. This fast-growing country has every reason to upgrade its workforce and economic drivers. Cambodia has to move away from a low wage economy to realize the 2030 and 2050 goals. As mentioned in documentation by the ADB, it is vitally important to shift toward a technology-oriented workforce that can produce high value-added commodities to foster long term growth (ADB, 2014).

In addition to the existing problem, skill shortages in the Science, Technology, Engineering and Mathematics (STEM) fields are also a significant issue that the government cannot overlook (Bruni, Luch & Kuoch, 2013). With specific occupations that require technical skills to perform, Cambodian youth do not meet the requirements or supply the quantity that commercial firms need (National Employment Agency, 2018). Most of the jobs that reported to have fewer vacancies are related to ICT and human health. (Kuoch, 2015). In 2014, ICT related jobs have the highest percentage of

skill-shortage vacancies at 49.3%, while jobs related to health show a considerable percentage at 34.1%. (Kuoch, 2015). These statistics indicate the gap in the STEM workforce in Cambodia. Notably, demand for high skill and skill intensive employment, particularly those in ICT, are likely to rise in the future.

Looking at the global trend, the world is transforming into a new era, the so-called "Industry 4.0'' which refers to a phenomenon that involves the intensive use of advanced technology. The Internet of Things (IoT), 3D printing, and robotics will alter the production process and boost productivity ("Industry 4.0 in Cambodia", 2019). As part of this global trend, countries are preparing for the digital economy by improving human resources in the STEM field. Human capital will be the source of Cambodia's success in Industry 4.0 due to its abundant young workforce that can compete globally when equipped with the necessary skills (Chhem & Ouch, n.d.).

With the aforementioned obstacles and problems, human resources in the STEM-related fields can play an important role and serve as one aspect of a solution to respond to the ongoing issues in the Kingdom. Human capital in the STEM fields is vital and necessary to move Cambodia up the global value chain. However, it has been found that many of Cambodia's youth either do not value the subjects or believe that STEM majors are too difficult to study (Kaing, 2016). Little attention or interest is shown toward this valuable component in Cambodian society which might contribute to the lack of STEM professionals in the Kingdom. Despite this lack of interest and passion for STEM, the Cambodian government has recognized its importance. The Minister of Education, Youth and Sports, Dr. H.E Hang Chun Naron, has emphasized the significant role of STEM education as the answer to current workforce problems (Kaing, 2016). The country may need to establish its STEM model to fit the social and cultural context of Cambodia which will ensure effectiveness and efficiency to produce a quality STEM workforce. In line with this vision, the Ministry of Education, Youth and Sports piloted the first STEM education model in 2014. Known as the New Generation Schools (NGS), these autonomous public schools have a mandate to improve the quality of public schools, especially in STEM education. Presently, NGS facilities have been established in nine locations across four provinces/cities (KAPE, 2019). This paper aims to examine the extent to which NGS have contributed to building a stronger STEM workforce for the

country using the four indicators - STEM strategic goals, student interest, student STEM literacy, and gender balance.

Consistent with the objectives of the study and the matters addressed above, the paper seeks to answer one main research question, and three sub-research questions.

Using NGS Preah Sisowath High School as a case study, what is the current state of STEM education in public schools in Cambodia?

1. Is New Generation School Preah Sisowath a successful STEM education model, weighed against the key indicators?
2. What factors enable and constrain STEM effectiveness in the New Generation School Preah Sisowath?
3. Given these factors, what can be done to make the implementation better?

A broad proposition in accordance with these questions is that STEM education in public schools in Cambodia has generally lagged behind its intended target given the lack of qualified trainers, low quality curriculum, and lack of practical materials.

# Literature Review

## Human capital theory: A look into STEM education

Generally, there are problems that developing countries commonly share. They include a low level of productivity and human capital (Bloom, Mahajan, McKenzie & Roberts, 2010). According to Todaro and Smith (2015) countries classified as developing states often fall into the poverty trap in which they experience an economic slowdown. They are not willing to invest in human capital due to low levels of income. This results in a low level of productivity and affects the economy as a whole (Todaro & Smith, 2015). As mentioned by Todara and Smith (2015), human capital refers to human health, education, and skill. These components are crucial to the growth of the nation (ibid.).

In the past, what was regarded as an important ingredient for economic development was physical capital. An economic approach that rests on the importance of human capital responsible for economic development is widely known as human capital theory.

This theory strongly emphasizes the role of formal education and how it affects individual performance on economic activity (Olaniyan & Okemakinde, 2008). This theory shows a positive relationship between education and the country's economic performance (Altiner & Toktas, 2017). Schultz (1961), one of the very famous human capital theorists, has referred to education as an investment for humans that will yield positive returns to them; the term coined by him was human capital (Schultz, 1961). Human capital is defined by Schultz (1961):

*Human capital as the knowledge and skills that people acquire through education and training being the form of capital, and that this capital is a product of deliberate investments that yield return.* (Olaniyan & Okemakinde, 2008)

Countries like Singapore, Hong Kong, and South Korea were once very poor countries. With their development model that invests heavily in education, a notable rate of economic growth occurred and now they are listed among the most developed countries in the world (Todaro & Smith, n.d.). However, the approach of measuring education levels through school attainment has been criticized as not appropriate to explain the link between education and economic development. (Sianesi & Reenen 2002, Islam, Ang & Madsen 2014). Cakmak and Gumus (2005) have claimed that increasing human capital is crucial but it is more essential for developing countries as workers with skills can work faster, utilize resources better and thus boost economic productivity (Holden & Biddle, 2016). To build a skill-based society that is pivotal for sustainable development, STEM is indispensable (Croak, 2018). One study conducted by Ray (2015) found that in the US, the number of STEM graduates yields a positive effect on economic growth (Ray, 2015). STEM education also addresses the problem of competitiveness in the international market, especially for developing countries (Zakaria & Iksan, 2007). Atkinson & Mayo (2010) also mentioned that without a STEM workforce, a science and the engineering-based economy is not feasible (Atkinson & Mayo, 2010). However, it is important to note that STEM education is critical to the enhancement of a technology-oriented society, but it is not necessarily the means to increase individual opportunities in the job market.

## History of STEM, Context and STEM education

STEM education has become the 21st century education trend. Both developed and developing countries have been pushing for more practical and effective practices of this specific type of curriculum. This rise can be explained by high STEM related workforce demand and the need for innovation (Capraro, Capraro & Corlu, 2014). Despite its trendy demand, the concept is not new as it has been around for a long time. (White, 2014). David White (2014) tracked back to as early as 1950 when Russia launched its first satellite project called ''Sputnik'', as a triggering component of STEM development (White, 2014). STEM stands for the four acronyms include Science, Technology, Engineering, and Mathematics. Heather and Jeffrey (2012) have defined STEM education as:

*Teaching and learning in the fields of science, technology, engineering, and mathematics. It typically includes educational activities across all grade levels— from pre-school to post-doctorate—in both formal (e.g., classrooms) and informal (e.g., afterschool programs) settings.*

STEM education is a type of study curriculum that applies concepts and discipline of the four subjects to solve real-life problems in order to develop critical, cognitive, innovative and creative thinking skills ranging from kindergarten to advanced higher education. It is important to mention that the four acronyms are not distinctive from each other. The STEM curriculum is a combination of the four scientific disciplines to form solutions that can solve abstract and deeper real-world problems (Kennedy & Odell, 2014). Kelley and Knowles (2016) named the term ''integrated STEM education'' and defined it as the combination of more than one STEM subject or the merging of STEM subjects and other normal school subjects (Kelley & Knowles, 2016).

**Figure 1** Conceptual framework of integrated STEM education

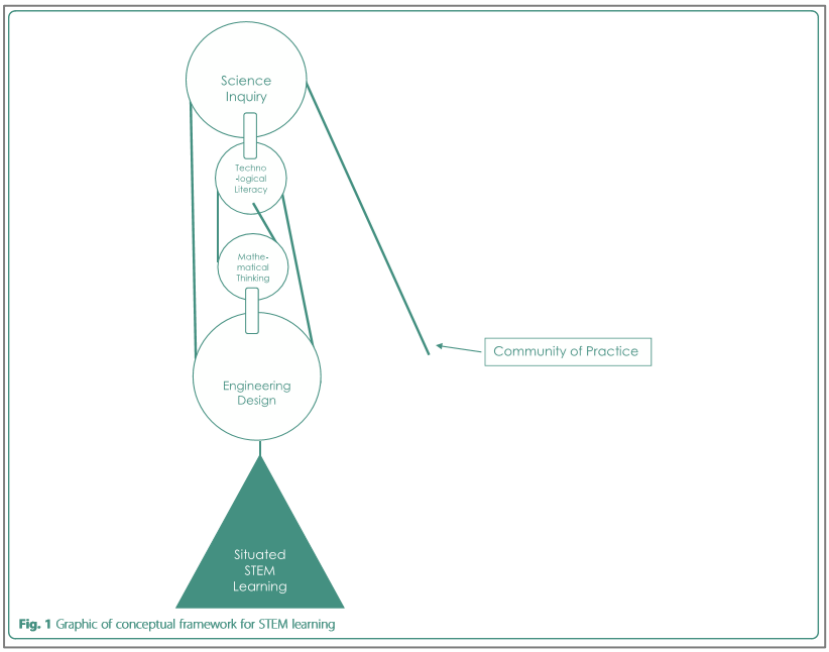



**Fig. 1** Graphic of conceptual framework for STEM learning

**Source** (Kelley & Knowles, 2016).

At present, there is no universally accepted definition for STEM education. Koonce, Zou and Anderson (2011) emphasize the significant role of a definition as one of the most important criteria to measure how successful and effective the program is (Koonce, Zou & Anderson, 2011). Without a clear distinction, the design of curriculum and pedagogy tend to be relatively weak and ineffective due to misunderstanding or misconception of the term. In line with the definition problem, a lack of comprehensive interpretation has often confused various STEM stakeholders such as government officials, educators, and STEM teachers in the interpretation of the term (Breiner & Johnson, 2012). This circumstance has caused STEM education variations in pedagogy and processes. Some use scientific discipline to conduct research, some focus on self-centralized study, while some use intensive technology such as robots and software to drive innovation. The question about what practices have the most effective outcome remain to be answered (National Research Council, 2012; Beatty & Alexandra, 2011).

The goals and objectives of STEM education are to improve STEM knowledge for all, to expand the number of STEM-related human resources and to improve high skill workforces (Holmlund, Lesseig & Slavit, 2018). To achieve the above objectives, the

participation rate plays a significant role in the successful implementation of STEM education. Yu Xie, Michale Fang and Kimberlee Shauman (2015), highlighted three key elements that influence STEM participation: contextual, family and individual factors (Xie, Fang & Shauman, 2015). With more students participating in STEM, the higher chance they will get attached to it and enroll in science-related majors after high school. Besides the problem of having a diverse definition, the misconception of Technology and Engineering in STEM also poses major constraints and challenges. As stated by David White (2014) and Stephen Portz (2015), Technology and Engineering in STEM education are the two most undervalued subjects (White, 2014 & Portz, 2015). Unfamiliarity of the two subjects to teachers or instructors and the perception that the T and E are concentrated more at the advanced and higher end of the education spectrum makes the implementation of an integrated STEM system less profound (White, 2014). The gender gap in STEM-related subjects should also be in policymakers' considerations as Yu, Fang and Shauman (2015) have categorized gaps in achievement, interest, race, ethnicity and participation. The research found that males tend to have the upper hand in terms of performance and interest compared to their female counterparts (ibid.).

## STEM in a Cambodian Context

If we look into the Cambodian context, there is minimal literature that focuses on STEM education. The lack of research may indicate that Cambodia's STEM is unfamiliar to the larger population and not recognized by the public. CDRI (2016) mentioned the irrelevance of global literature of STEM education in the Cambodian context (CDRI, 2016). The uniqueness of Cambodian culture and society may not allow existing literature available on the internet to be applied such as that which focuses on race or ethnicity (CDRI, 2016). The journal also mentioned, in the context of Cambodia that, further research should take into account external factors such as social, cultural or economic determinants that may influence STEM participation (CDRI, 2016). Successful STEM education models vary through different contexts and societies. As important as

it sounds, there is no finding yet on the most effective STEM model for Cambodia to implement. Well established research with the right goals, pedagogies, and curriculum will add high value to Cambodia's STEM education. The implication of previous research for future study is to find the factors that motivate those who perform well on STEM subjects during high school to choose non-science majors at universities (CDRI, 2016). The research on Cambodia's STEM education should be based on a social-cultural perspective to achieve equity results and reports suggested that a comparative approach is ideal to explore Cambodia STEM developments (CDRI, 2016).

A study by Sovansophal (2013) underpinned the factors that influence a student's preference for pursuing Science and Engineering majors in higher education in Cambodia (Sovansophal, 2013). The paper aims to understand the internal and external factors that affect a student's choice of majors. It concluded that individual performance in science-related subjects and their preferences impact choice the most, whether negative or positive. (Sovansophal, 2013). While family background such as parents' occupations and teachers' roles yield immense influence on students' preferences, gender and family revenue are the factors that constrain students from choosing Science and Engineering majors (Sovansophal, 2013). Another study conducted by Eng and Szmodis (2016) also added important value to the current state of STEM education in Cambodia. The research focused on gender disparity in STEM achievement. What was found is surprising. There is minimal difference between males and females in terms of STEM performance in secondary school (Eng & Szmodis, 2016). This contradicts global literature that shows that male perform better, have more interest and higher participation rates compared to their female counterparts in STEM-related fields.

There has not yet been enough study to address this educational system to allow us to understand the STEM model in Cambodia in such areas as the current state of STEM, student performance and outcomes, gender performance, etc. The concept of STEM is new to the country so not much attention or awareness has been given to it. This study will add a substantial source of information to the comprehension of the Cambodian STEM model. It will be valuable for further research to build upon this significant model of education and provide a basic understanding to Cambodians about STEM education, the challenges to its implementation and the teaching pedagogy.

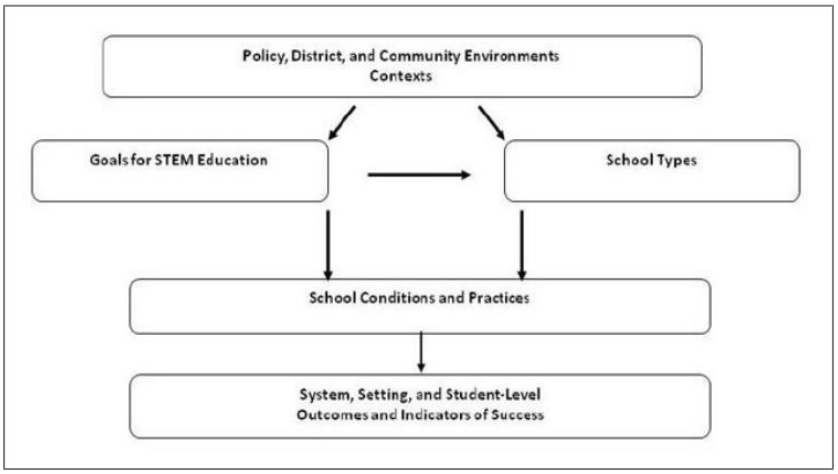
# Research Design

## Conceptualization and Operational Definitions

Since there is no universally accepted definition of "STEM education", it is necessary to conceptualize the term. STEM education refers to a specific type of education system that concentrates on the teaching of the four STEM subjects (science, technology, engineering and mathematics) in a multidisciplinary approach to solve real world problems through different teaching pedagogies such as inquiry-based learning and project-based learning (PBL).

With a variety of definitions of the term come a great number of indicators and measurements that are available to broadly measure the degree of how successful a STEM school is. Alexandra Betty (2011) has designed a framework that is used to measure the success of STEM schools in their research (Beatty & Alexandra Beatty., 2011) (Figure 2). The framework consists of goals for STEM schools, including school type, school conditions and practices, student outcomes, and school system. However, due to time limitations and resources available, it is not possible to measure the success of a STEM school based on all of the mentioned criteria in our research. This study will design an exclusive indicator to measure STEM schools based on various global literature that reflect Cambodia's social and cultural context, the feasibility of the study, research limitations and the period of establishment of the school.

**Figure 2** Successful framework of K-12 STEM education




**Source** (Beatty & Alexandra Beatty., 2011)

First, the ability of schools to stimulate student interest in STEM is considered to be a main component of a successful STEM model (Makhmasi et al., 2012). Various literature found that when engaging students in STEM subjects such as science and mathematics, they tend to get bored and lose interest in the long run due to the discipline and complexity of how the STEM school and the curriculum has been laid out. It is vital for the school to keep the interest of students in the school (Ejiwale, 2013; Makhmasi et al., 2012). Hansen (2013), did something similar in terms of measuring STEM school student interest. He looked into such criteria as student perceptions of how they felt about their classroom environment, teachers, teaching methods, class activities and so on. (Hansen, 2013).

Secondly, the research will take a look specifically at the goals and objectives of the STEM school and how well the school has achieved those set targets. Guidelines and objectives of the school are crucial and necessary components to contribute to the success of the STEM model (Ministry of Education and Skill, n.d.). Goals and objectives of the school are the ultimate target to be achieved. As well, the goals of STEM schools should concentrate highly on STEM performance and students/teachers development and outcomes. (Ministry of Education and Skill, n.d.).

Another indicator used to measure success is STEM literacy. According to the NRC, STEM literacy is "the knowledge and understanding of scientific and mathematical

concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (A framework for K-12 science education, 2012). STEM literacy can be measured in many ways such as students' test scores in specific STEM subjects, achievement and study outcomes, basic understanding, and measuring how students have used what they have learned to deal with problems in daily life (Peterson, 2017). Due to the time constraints and data availability, it was not possible to measure student STEM literacy by comparing their scores or performance. Hence, STEM literacy in this study will measure specifically on how students have used what they have learned in class to deal with real life problems and their confidence in expressing their knowledge of STEM subjects in public.

Lastly, this paper also aims to examine the gender balance between male and female students as well as their degree of involvement and participation in class. The participation rates and interest in STEM subjects according to gender are an outstanding indicator to measure and define the degree of success and effectiveness of the school. At the global level, only 30 percent of women are enrolled in STEM related fields of study (UNESCO, 2015). This reflects gender inequality and underrepresentation of women in the fields (Kao, 2019; UNESCO, 2015). Gender imbalance in this particular field can yield negative economic impact to a country as half the population are women. Given the low participation rate of women in STEM fields, large numbers of human resources are left out. It is crucial for a STEM school to balance the genders in order to provide equal opportunity for all to partake and participate in STEM.

**Table 1** Successful key indicators of STEM education

| Key indicator | Operational definitions |
|---|---|
| Student interest | Student perceptions of the school, classroom, teachers, environment, facilities etc.<br>Student participation rate<br>Student perception of STEM subjects<br>Student perception of the pedagogy<br>Students' future endeavours, whether they pursue STEM as major/career |
| Student STEM literacy | Students' ability to apply STEM concepts and discipline to solve real world problems<br>Student confidence in expressing STEM knowledge in public |

| | |
|---|---|
| | Student ability to solve STEM test |
| Goals and objectives of the school | STEM oriented goals and objectives<br>Students/teachers outcome-oriented goals and objectives |
| Gender balance and participation | Male and female ratio in STEM<br>Male and female performance in STEM subjects<br>Male and female participation in class |

## Research Methodology and design

For this research case study, New Generation School of Preah Sisowath high school was selected. There are many NGS across the country and there are a variety of STEM schools currently operating in the Kingdom. NGS Preah Sisowath was chosen, however based on three main reasons. First, the NGS program is administered under a Ministry of Education, Youth and Sports (MOYES) initiative which is collaboratively operated by Kampuchea Action to Promote Education (KAPE) which qualifies it as a public school. As a public-school model, it has the potential to be expanded nationwide. Secondly, NGS Preah Sisowath Highschool is the most well-established with the best infrastructure, study equipment, computers and experimental lab. as well as its location in the heart of the city. This is suitable for our research to see the performance of the model in its full-scale implementation as well as the progress of the students. NGS at Preah Sisowath Highschool was one of the first NGS initiated by the government in late 2014. This is an appropriate period of time to examine its progress and achievements. Moreover, a four-year period of time allows the school to demonstrate its influence and effectiveness toward student performance and literacy and show how it has shaped student interest and perception.

This study employs a mixed research methodology to measure the perceptions of different stakeholders involved with STEM education including school principals, teachers, and students. This methodology will allow the researchers to understand the perspectives of both the supply and demand-sides toward STEM implementation in Cambodia. Both qualitative and quantitative research designs are employed to collect pertinent data to provide in-depth information for meaningful analysis. Semi structured interview questions were designed to identify the perceptions of the participants

concerning the implementation of STEM models in such areas including the challenges, opportunities, visions, and goals. The interviews allow the researchers to understand critically and in-depth the essence of the analyzing components. In addition, the interviews provided the opportunity to exchange knowledge and understanding of the goals and future of the STEM school. For teachers, another semi-structured interview was conducted, particularly for NGS STEM subject teachers. Questions about their difficulties and obstacles in delivering or teaching the lessons using the STEM approach were asked. The interview also attempted to identify other constraints that otherwise would not happen in a normal school such as the limitations of equipment and additional teaching materials, teachers' knowledge and understanding of STEM approaches and disciplines as well as what changes they would like to see. The answers will be an important addition to the data constituting the development of research on Cambodian STEM education. Last but not least, an online close-ended questionnaire was administered to students of the NGS school. The online questionnaire was the most efficient way of getting access to interview students for the respective case studies. The structure of the questionnaire was formulated to discover student interest in their school including the classroom environment, the curriculum, their teachers, pedagogies, the in-class activities and their interest toward STEM-related fields in general. This has provided extensive information and adds extraordinary meaning to the research data which answers our main research question. Major limitations to the sampling and methodology selection was the access to NGS Preah Sisowath High School to collect relevant and important research data. Data such as yearly spending and budgets, students monthly test performance, monitoring and evaluation papers which are all crucial for research analysis are inaccessible to the public.

The research population identified and selected includes one Senior National Advisor of KAPE organization, one school principal from Liger Leadership Academy and one school principal from E2STEM. The researchers were also keen to hear from the teachers' point of view and invited three teachers from NGS Preah Sisowath High School including Biology, Mathematics and ICT teachers and one Geography teacher from E2STEM for an interview based on the snowball sampling method. The study also randomly selected one class of thirty grade 11 NGS students to answer an online

questionnaire. Due to data accessing difficulties, the study used simple random sampling in selecting the research population based on a voluntary basis. The questionnaire reached out to 70 students with 30 agreeing to be the research population.

# Findings and Empirical analysis

## Case study: New Generation School of Preah Sisowath High School

### The Current State of Cambodian STEM education

In order to understand deeply of the meaningful implementation of NGS Preah Sisowath, it is essential to understand the initiative of New Generation School as a whole first. The New Generation School is a collaborative project of the MoEYS (Ministry of Education, Youth, and Sport) and KAPE (Kampuchea Action to Promote Education), a leading education non-profit organization in Cambodia. This is a major attempt by the Cambodian government to modernize and reform the country's education system. According to KAPE's Senior National Advisor which is the organization in charge of the initiative, the goals and objectives of creating the New Generation School are to modernize and reform the Cambodian education system through good governance, financial transparency and accountability and provide a modern, 21st century way of learning focusing specifically on the STEM education approach.

*"What we try to change is the traditional thought of the society in Cambodia's public schools. The view of the citizens on public schools is generally negative such as corruption, poor standard of teaching and learning as well as the quality of education as a whole" (Personal communication, September 11, 2019).*

Currently, there are 9 NGS operating across the country in both provinces and cities such as Phnom Penh City, Kandal, Kompong Cham, ranging from kindergarten to high school ("New Generation School", 2019). Claiming to be the first Cambodian charter school, NGS is the first public-private school which functions in accordance with the KAPE administration. It is not bound by government authority. This is in contrast to the normal public schools where all decision-making power is under the MoEYS' authority (personal communication, September 11, 2019). Having joint autonomous power between the private and public partnership will enhance teaching effectiveness, quality, efficiency as well as improve transparency within the school. It is in the government agenda to further expand on this pilot project to various schools across the country so

that equal opportunities are given to students in the provinces and rural areas (personal communication, September 11, 2019).

This project was first piloted by KAPE in 2014 in Kompong Cham province. It then received increasing attention from the Ministry of Education as the potential of the project was recognized with to expand across the country. This public-private school follows the school in school model which means that every NGS is located in a public school. For example, NGS Preah Sisowath is located in Preah Sisowath High School. Using the school in school model to implement NGS minimizes as much as possible such expenses as spending on building a new school. This would otherwise be very costly for the government budget (personal communication, September 11, 2019). The same source continued, to say that another purpose for building NGS inside the existing public schools is to change the negative perception of Cambodian public schools (personal communication, September 11, 2019). There are criteria KAPE has set in choosing which school is capable of implementing the NGS project which can be seen in the New Generation School Policy Guidelines. The criteria include, the school setting, its infrastructure, and degree of commitment. The participating schools have to perform and follow the policy and guidelines of the NGS. Evaluation of school performance is done annually by the Oversight Board to see if the school can keep up and achieve NGS standards and goals. If the school fails to achieve or violates any of the criteria, MOYES and KAPE are in a position to cut funding and end the NGS initiative in that school (personal communication, September 11, 2019). Even though NGS is a public-private partnership, it still qualifies as a public school since it is under the administration of the MoEYS. Finance is fully supported by the ministry under KAPE's management to ensure transparency, efficiency and effective use of the funds. There is a financial monitoring body created by KAPE that operates within NGS to keep track of the spending budget (personal communication, September 11, 2019). What is interesting is that after three years of establishment and when the school qualifies as an NGS, KAPE and MoEYS will stop their portion of the funding. Income will then be generated through parents' voluntary donations based on family background and income (MoEYS, 2016). For example, earlier in June of 2019, the New Generation School of Preah Sisowath High School held a family consultation meeting to discuss the purpose of parents' financial

contributions to the school. $280US is the standard donation (personal communication, September 11, 2019). They can donate more depending on their ability or wanting to make the school better, he continued. However, this process is also voluntary. Students who come from less fortunate backgrounds are not required to make yearly contributions but may give any amount voluntarily.

Located inside Preah Sisowath High School, this NGS occupies more than five buildings. Currently there are 763 students of which 339 are female. NGS PSH hosts students from grade 7 to 12 and is divided into 24 classes consisting of three classes of grade 7, four classes of grade 8, six classes of grade 9, three classes of grade 10, four classes of grade 11 and four classes of grade 12 for the 2017-2018 academic year.

**Table 2** Information of classes and students in NGS Preah Sisowath

| | **Grade 7** | **Grade 8** | **Grade 9** | **Grade 10** | **Grade 11** | **Grade 12** |
|---|---|---|---|---|---|---|
| **Number of class** | 03 | 04 | 06 | 034 | 04 | 04 |
| **Number of students** | 102 | 134 | 195 | 100 | 123 | 109 |
| **Number of female students** | 38 | 59 | 83 | 54 | 56 | 49 |

As of 2018, there were 59 teachers at NGS Preah Sisowath including 30 female teachers. There is one meeting hall, three chemistry classrooms, three for biology and three physics classrooms that have built-in experimental laboratories. There are also three ICT labs with 39 on desk computers for students. Furthermore, this well-organized school is equipped with high standard, modern education materials which have not been seen in other public schools. Such items include good quality desks and chairs, projectors, attendance fingerprint scanners, and air conditioners.

NGS Preah Sisowath is the first Cambodia public focused STEM school to introduce 21st-century teaching and learning methods to Cambodians. It focuses on a student-centered approach and project-based learning to maximize STEM effectiveness. This is the key factor which distinguishes NGS from normal public schools where the latter

focus on a teacher-centered approach. In the student-centered approach, the opportunity gaps between students are reduced as it allows them to talk and act more independently in class compared to the teacher-centered approach (McKenna, 2014). Students are the main players as they take control of the class while the teacher's role is to facilitate and initiate discussion, lessons, exercises, and in-class activities. (McCarthy, 2015) This is to complement the 21st century way of learning on which NGS tried to boost teaching standards, quality, and student outcomes (S. Kim, personal communication, 27 october 2019). In addition, other teaching methods have also been implemented including project-based learning, inquiry-based learning, brain-based learning, and cognitive-based learning, etc. Student-centered is the most common and effective education tool to illustrate STEM-related discipline and lessons (LaForce et al., 2016). Similarly, another prominent STEM school in Phnom Penh, namely, E2STEM also practices this type of pedagogy. Students are encouraged to speak during classes, lead discussions and be more active compared to the normal curriculum (personal communication, 2019) This clearly shows that Cambodia's STEM education is moving in the right direction given the fact that they have chosen this approach to implement the curriculum. As claimed by Run IU, a senior national advisor of KAPE, this approach will allow Cambodia students to develop critical thinking skills, creative thinking capacity and will prepare them with the soft skills required for the future workforce.

*"This is a modern approach to learning and teaching. We usually only see this kind of teaching in higher education in Cambodia. Students centered learning will help the kids to do things on their own, developing their critical thinking capacity, enhance their confidence and public speaking skills which are the skills needed for the 21st-century career path. Students can never learn these skills in normal public schools" Run UI (2019).*

Another important approach that accompanies student-centered learning is Projected Based Learning, which is applied to and practiced in all subjects, especially in STEM subjects. Not limited only to NGS, other schools also apply this practice. This is a very effective approach to illustrate and realize the meaningful STEM disciplines. Students get to explore hands-on experiences, engage in real-life activities, understand the objective and goal of a task clearly and more importantly get to communicate among their peers (Jarmila, Antonín and Martin, 2016). Students will develop critical thinking

capacity from problem-solving and results-oriented activities. The author continued that, PBL will create room of creativity for students to integrate different disciplines and concepts that they have learned to solve the problems (Jarmila, Antonín and Martin, 2016). This is the fundamental approach that is widely used to engage students in learning activities and maximize their STEM understanding and literacy through real practice. For instance, at NGS Preah Sisowath, during coding class, groups of students are assigned to work together applying the concepts and disciplines of coding to create something practical in real life such as a mobile application to showcase traditional Khmer sculptures that can be downloaded throughout the country.

## Indicators of Successful STEM Education

To answer the sub research question for seeking the successful STEM model to implement, it is necessary to understand the degree of success of the New Generation School at Preah Sisowath High School. To measure its successes, four indicators have been determined based on research limitations and study feasibility, that is, the goals and objectives of the school, student interest toward STEM and the school, student STEM literacy, and gender performance and participation in STEM subjects of the school.

### Goals and objectives

One of the important components to measure the degree of a STEM school's success is to understand the purposes of its goals and objectives (Successful K-12 STEM education, 2011). Generally, the ultimate goal and objective of STEM schools are result-oriented and are heavily focused on STEM outcomes and student literacy. On the other hand, according to the New Generation School policy guideline which can be accessed through the MoEYS' website, goals of NGS are to create an autonomous public school that acts independently from the government and aims to create a modern, 21st-century education institution for Cambodia citizens. Also, NGS's objective is to reform the Cambodian education system in terms of quality, transparency, and efficiency by placing great stress on the principle of good governance and the creation of a monitoring body to oversee school performance and progress. This is a steppingstone toward quality education.

Nevertheless, the study found that NGS Preah Sisowath has had considerable success in achieving its goal and objectives of transforming into a 21st century school by infrastructure improvement, good governance, teacher development and improved capability. The school is well equipped with modern study facilities such as favourable classroom environment and furniture for active learning principles, a 21st century library for independent study and development, and the creation of various laboratories for different subjects. This is a massive achievement when compared to the normal public schools which use traditional and out of date materials. Also, the focus on teacher development and capability is impressive at the New Generation School. Teachers usually get onsite training from education experts assigned by KAPE on teaching methodology (personal communication, 27 October 2019). They also have the chance of getting a scholarship abroad to further build up their teaching career. Additional incentives above their regular salaries are based on their teaching performance. This is regulated by a monitoring and evaluation body at the school (ibid.).

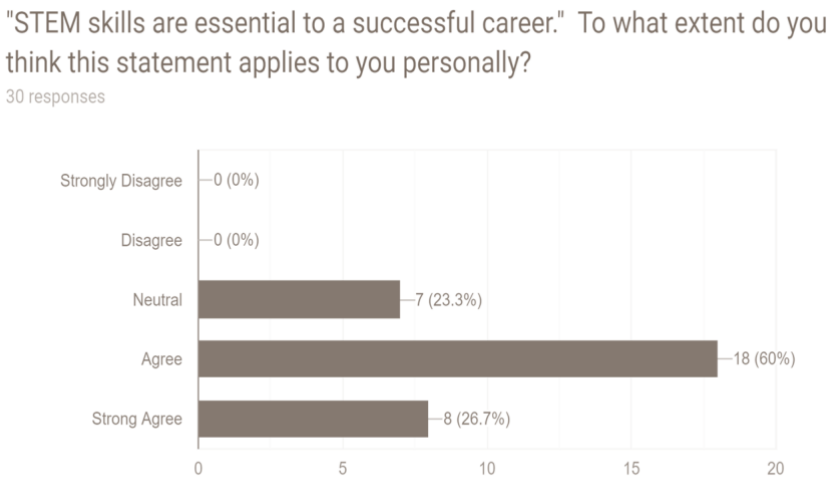
### Student interest

With the establishment of STEM schools, one of the ultimate goals are to improve student STEM literacy and to enhance and maintain their interest in STEM fields. Student interest and literacy is one of the significant factors that defines the STEM school success. In this research, a class of 30 students in grade 11 at NGS of Preah Sisowath High School were asked to answer an online closed ended questionnaire on their personal interests, perceptions and preferences on their school, teachers and STEM in general. Overall, the results show that NGS has done an excellent job cultivating students' interests and enhancing their enjoyment in studying STEM. In general, students responded that they enjoy the classroom environment, the in-class activities and the teaching pedagogy. However, in terms of STEM literacy, students often found themselves lacking confidence when expressing knowledge as well as when using the content, they have learned to deal with real life practice. This might be explained as a lack of understanding due to the poor performance of teachers to perform in STEM approach and transfer STEM content to students.

Respondents to the questionnaire consisted of 63% male and 37% female participants or 19 and 11 students respectively. It is important to point out that 70% of the

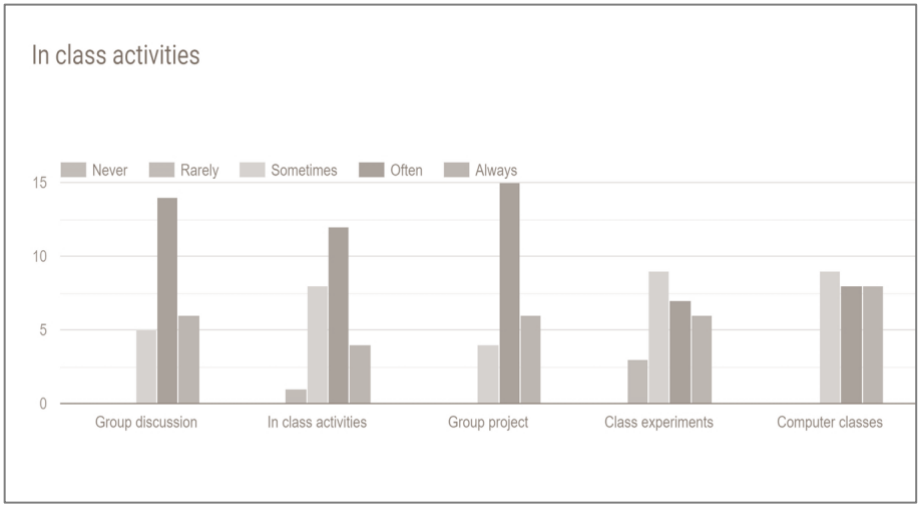
population have been studying for more than 2 years at NGS Preah Sisowath. This is considered an appropriate period of time to measure the effect that NGS Preah Sisowath has had on students in terms of their STEM literacy. According to the online questionnaire, only 30% of the students had enrolled to study at STEM school as a result of teacher and family persuasion while the rest of the population registered due to their own will. This can be interpreted as showing that students at NGS are enthusiastic about STEM subjects and will be more likely to pursue these subjects at higher levels of education. All of the respondents truly believe that STEM skills are essential for their future career endeavors. This can be used as another indicator to illustrate the strong degree of trust that students have in STEM related subjects in terms of their career path.

**Figure 3** Student's perception survey




Students generally held positive thoughts toward their school and teachers. In their perception, teachers at NGS have done exceptionally well at explaining the content of the lessons and answering students' questions. According to the questionnaire, students' favorite STEM subjects are mathematics, science, and technology, respectively. Finding the subjects interesting and having the willingness to learn new things are the key motives behind their favorite subjects. They also show enjoyment in studying and are very excited to go to school. The major reason for that excitement is because they enjoy studying at the school with the classroom setup and environment. Additionally, the study found that students actively participate in group discussions, group projects, class experiments, and computer class, etc (figure 4). The high participation rate is the proof and result of the attraction that the curriculum and program have offered to students. This is an effective approach in line with the active learning principle which requires a high level of involvement.

**Figure 4** Participation rate in different activities




This outlines a relatively successful implementation of the model that has kept students enjoying learning as well as enhancing their motivation to go to school. As mentioned in the literature review section, keeping student interest in STEM subjects is one of the ultimate goals of STEM school. Further evidence shows that in-class activities such as group discussions and on-hands experiments in STEM subjects are what keeps students motivated and excited to learn at NGS Preah Sisowath High School.

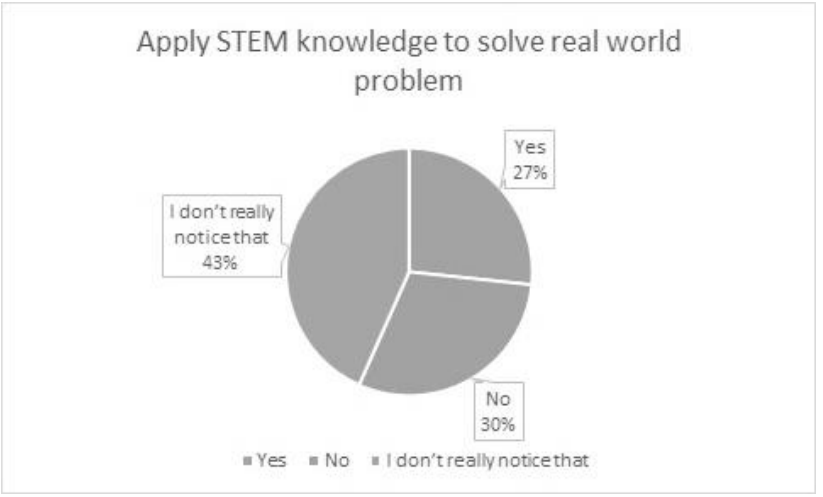
### Students' STEM literacy

Complete data on STEM literacy was limited. The monthly test scores are not available to the public and the request to get access to those data were pending but ultimately rejected. Instead, the research sought in-depth information of students' STEM literacy by inquiring as to their public confidence in expressing their knowledge, their ability to solve their monthly test questions, their ability to apply STEM literacy to solve daily problems. As well, the paper will look into NGS students grade 12 national examination pass rates and student medals and achievements in various local and international STEM related competitions which are all publicly access information.

When asked whether or not they have applied what they have learned in class to solve daily life problems, only 27% answered yes while the other 30 percent responded with no. The other 43% have never noticed whether or not they have applied the knowledge they have learned in school.  Students indicated that they find it extremely difficult to

solve various STEM exercises and test questions that teachers have assigned. The most difficult and complicated of these are engineering-related subjects, followed by Science and Math. As the questionnaire showed, students struggle to answer specific questions in STEM-related subjects, particularly on the assigned exercises and monthly tests. This can be interpreted as the consequence of low STEM literacy. Understanding of it may be the result of an ineffective curriculum or teachers who are not able to deliver expected STEM content to students. On the other hand, when looking into exam-based assessments, NGS PSH students have done brilliantly on the grade 12 national state examinations. According to the NGS annual report 2018, 89% of all NGS Preah Sisowath exam candidates passed the 2018 grade 12 national exam. To compare, nationwide grade 12 examination pass rate is 66 percent. Moreover, in terms of non-exam-based assessments, NGS students have competed in various STEM related competitions both at the local and international level and have won 128 medals in 2018 (KAPE, 2018)

**Figure 5** Applying STEM knowledge to solve daily task




## Gender Equality, Performance, and Interest

According to Boutilier(n.,d), gender equality has always been one of the challenges to STEM implementation (Boutilier, n.d.). Women have significantly lower interest and participation rates toward STEM-related content and majors compared to men, especially those in engineering and technology (UNESCO, 2017). In general, men dominate the sector and perform better compared to their female counterparts (ibid.).

The participation of women in the economy in terms of STEM-related areas contribute significantly to productivity rate and economic development. Economic development and productivity can be improved when more females start to partake in STEM fields. In NGS, gender balance is not an area of focus at the school. There is no gender balance or mention of equality in the goals, objectives or policy in the New Generation School operational guidelines at all. This can translate to a lack of awareness in terms of gender balance in STEM education in Cambodia. However, even without any set goal or target, the study found out that the female gender is doing just as well as men in school. As of 2018, 339 female students' study in NGS Preah Sisowath which accounted for nearly 50 percent of the student population. The participation rate is also indistinguishable between the two genders. From teacher observations, female students are just as passionate about participating in class activities, group projects, and other STEM-related content such as coding class and ICT class. Moreover, other STEM schools such as the Liger Leadership Academy and E2STEM also showed a positive gender balance. The Liger school, for example, achieved an impressive 50-50 gender rate at the school. Women's participation and gender balance can also be seen at national and international STEM related events. For example, for a robotics competition, a group of students from E2STEM consists of more female than male students. These numbers are all evidence to conclude that in terms of gender balance, equality and participation in the Cambodian STEM context do not pose the same problem as it exists in most other countries of the world.

## Challenges to Cambodian STEM education

During our data collecting process, we interviewed individuals at different STEM institutions in Cambodia as well as four STEM teachers at NGS to ask them about their perceptions, difficulties, and constraints on teaching at NGS as well as the new approach to teaching. From these interviews, similar answers were given by the teachers. Three challenges have been identified that pose major challenges to effective STEM

implementation and STEM teaching. They are financial constraints, quality teacher recruitment and the STEM approach to teaching.

### Financial Constraints

Arguably, financial constraint is a problem for all education systems. In Cambodia, the cause of financial problems in implementing a STEM education model are high costs and low financial support and investment. The implementation of STEM education requires an immense amount of facilities and equipment that is costly, especially the advanced technology needed to unleash and maximize the full potential of STEM education (Dogan & Robin, 2015). Intensive use of technology integrated into the teaching curriculum is crucial for students to become familiar with technological advancement and to get hands-on experience of STEM disciplines (ibid.). Computers are among the most necessary components in STEM education (Mark Guzdial, 2019). For instance, at NGS Preah Sisowath where there is a maximum of 36 students per class, the school has purchased 39 computers to ensure there is always enough equipment. This number can vary depending on the school budget and the size of students per classroom. In the Cambodia context, it is not affordable and economical to purchase a great number of computers for students as the spending budget is limited.

The spending list is larger for STEM schools due to the costs of high-end study equipment, materials, facilities, in-class activities and monthly support for teachers. Equipment and facilities costs are extravagant compared to the country's GDP and budget spending. Expensive hands-on experiments and equipment for each STEM subjects such as computers for coding, chemicals substance for chemistry and physics class, microscopes for biology class, etc., are all necessary components in STEM education to enhance student experience and knowledge as well as to support the active learning principle. STEM content is complicated. Without modern equipment and practices, STEM implementation is not effective and will not deliver the expected knowledge to students (UNESCO, 2019). For example, during biology class, teachers struggle to perform specific activities without microscopes, something that is not affordable within the NGS budget range (personal communication, 27 October 2019).

This factor restricts teachers to illustrating the lessons. Without a practical hands-on approach, students will not be able to fully understand the content of their subjects.

During the interview with the KAPE Senior National Advisor, he noted that even though the budget of NGS is high, there are still limitations on being able to implement the full potential of the STEM model (personal communication, Run IU, 11 September 2019) The cost of one student at a regular public school per year is estimated to be around 119 USD ("Education and training", 2019). This is significantly lower compared to the cost of students per year at NGS which is estimated to be 462 USD (KAPE, 2018). It is more than twice the budget of the regular public schools. This is the biggest barrier for the government to consider when modernizing the public schools. However, not all NGS costs per student per year are the same. It depends on different factors such as the location of the school, equipment, facilities and the school budget. The cost per student annually varies among different NGS. For instance, at NGS Svay Rieng, the cost per student is estimated to be around 200 USD (KAPE, 2018).

On the entire spectrum of STEM schools currently operating in Phnom Penh, the NGS school model is considered a mid-range STEM school. At E2STEM, study costs per student are around 300$. This is slightly less than NGS due to the fact that E2STEM hosts a smaller number of students. There are approximately 110 students with fewer teachers (personal communication, 19 October 2019). Also, it is understood that E2STEM is not equipped with a modern library or as many science laboratories as NGS Preah Sisowath which makes the budget smaller. In terms of quality and student outcomes at E2STEM, it is yet to be seen as this school was only launched in late 2016 and there is no study specifically addressing school performance yet. A more prolific and high-profile STEM school, Liger Academy costs about 4,650 USD per student annually. This high cost school is very well equipped with modern equipment and facilities necessary to fully implement the STEM discipline. For example, it has a high-end computer lab and 3D printer. The quality that is delivered at Liger Academy is as expected. Their students are the most prominent in terms of STEM literacy when comparing the three models. However, given its extremely high cost, it is not feasible to implement throughout the country.

### Quality Teacher Recruitment

Another challenge to effective STEM education is quality teacher recruitment. In the Cambodian education system, teachers at public schools often possess poor teaching ability and knowledge. They are not well trained and receive a relatively low salary causing the quality of teaching to decrease as well. In contrast, recruitment does not face any significant difficulty if the criteria are set for foreign teachers.

There is an immense human capital gap between Cambodians and foreigners that needs to be acknowledged (personal communication, 28 August 2019). In the Cambodia STEM education context, the recruiting of qualified teachers is a tough challenge. The content in the STEM curriculum is well advanced and includes a variety of scientific and technical terms. Within the STEM approach, teachers play a significant role in transferring the knowledge and content to students as well as to facilitate the in-class activities (Keiler, 2018). Moreover, to perform high-quality content, teachers need to possess a high degree of knowledge and understanding of STEM. What is more, some STEM content requires real people who work in the field to illustrate and facilitate the lessons. For example, in an engineering class, the school hires a real engineer with expertise in wood carpeting to perform a specific project that is in the curriculum (personal communication, 28 August 2019). At NGS Preah sSsowath, a large proportion of the teachers consist of young, energetic individuals who are enthusiastic about the modern approach to teaching as well as STEM curriculum (S. Kim, personal communication, 27 October 2019). Only Khmer nationals are eligible to teach at NGS and are required to go through the selection process and interview. As a result, teachers at NGS have often underperformed to the expected outcome and standards and were faced with teaching difficulties that will be discussed further in the following section.

Besides expertise and knowledge, another important factor is the characteristics of the teachers. Teachers at NGS needed to be well equipped with a sense of humor, passion, and a commitment to teaching. “Teaching at NGS is a full day job so it requires teachers to be fully committed to teaching which is different from the normal public school where they have more free time to teach private tuition and earn extra” (personal communication, 29 August 2019).

*"Since the aim of NGS is to build young STEM professionals for Cambodia's future as well as to modernize the education system, recruiting teachers requires two important factors which are knowledge and characteristics". (Personal Communication, 29 August 2019)*

Good characteristics and commitment are essential for teachers to be equipped with in order to teach within NGS environments such as a whole day class program, 21st century learning mindset and high standard of teaching that has been set forth in the NGS policy guidelines (Ministry of Education, Youth, and Sport, 2016). Characteristics and commitment are as important as their ability to teach. The senior National Advisor of KAPE states "Sometimes, skills can be taught through various training however characteristics such as, a sense of humor, belonging and responsibility cannot be transferred through the training session, it needs to come naturally from the individual". Additionally, following the e-learning principle, NGS teachers have to be able to use electronic devices, online communication platforms, and have their own personal laptops. For example, communications used to interact between students and teachers are through email and online platforms like Google drive. Teachers need to be fluent and familiar with all of those platforms. This is another key criterion that is required and usually what most Cambodia teachers lack, especially those from rural areas.

### The new approach to teach STEM

The new approach to teaching, particularly STEM and the student-centered approach is a challenge that has been identified by STEM teachers currently working at NGS Preah Sisowath. Even though the curriculum of NGS is identical to a normal public school, teachers still need to apply and practice the STEM approach to teaching. The STEM approach can be defined as "approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects" (Kelley and Knowles, 2016, p.2). The integration of different STEM teaching methods allows students to be more critical as well as flexible in terms of critical and creative thinking capacity (Stohlmann, Moore and Roehrig, 2012). Also, this interdisciplinary approach helps students become familiar with the concept of STEM and how it can contribute to solving real-world problems. This approach requires immense training, practice, and experience to deliver the desired

outcome. New Generation School teachers are often faced with the difficulty of conducting this teaching approach (Personal communication, 28 August 2019). Teachers at NGS Preah Sisowath often found themselves lacking the foundation of this teaching method. This has led to teaching ineffectiveness as the content of the lesson was not delivered according to the expected outcome and purpose.

*"It is a new approach that I am not familiar with so it is very difficult at first to demonstrate the lesson,'' (Personal communication, 28 August 2019)*

After being selected, limited training sessions are provided for teachers about teaching ethics at NGS and STEM pedagogy. The training usually lasts two to three weeks. Lack of training has caused teachers to face this challenge since they are not able to fully demonstrate the lessons properly. Teachers admitted that getting students to talk in class and finding ways to keep STEM lessons interesting is challenging. The NGS teachers continued that this approach is not only new to teachers but also students. Cambodian students are more familiar with the teacher-centered approach so when the new method is being adopted, they do not tend to cooperate. They choose to stay in their comfort zone. Without student participation, the student-centered approach is not effective. Creativity will play an important role to keep students enjoying the subjects and at the same time encouraging them to talk in class.

## Synthesis

Using the successful measurement framework based on the four indicators, NGS SSW is a promising STEM model for Cambodia. It is an outstanding STEM model considering its budget and successful implementation. Of all indicators, NGS has had massive success in achieving its goal of modernizing the traditional teaching school changing into a modern, 21st century one in accordance with STEM learning and teaching approaches. NGS SSW is considered effective given the fact that it has cultivated student interest to prefer STEM subjects and enjoy learning STEM as well as developing teacher capability. From the research findings, key variables have been identified as the challenges to the implementation of STEM education in the country. Within Cambodia, finance is one of the most pressing obstacles that Cambodian STEM schools have faced,

followed by the difficulty in recruiting qualified STEM teachers and the problem of illustrating the STEM teaching approach which is new to Cambodia teachers

As discussed, the goals and objectives of the school are targeted to improve the operating process inside the school which has always been one of Cambodian education's biggest weaknesses. The introduction of good governance and transparency within the school is a welcome change. Moreover, the improvement in teacher capability is the direction that every school in Cambodia should take in order to improve the quality of education. Also, the addition and installation of modern equipment and facilities such as a modern library, experimental laboratories and integration of technology into students' daily tasks are in accordance with the goal of creating a 21st century school. Secondly, student interest toward the school has been positive. According to the questionnaire, students show enjoyment in studying and going to school. Students also express their profound interest toward teachers and STEM teaching approach. This is a significant component to achieve a successful implementation of STEM education. Without the lack of interest, students are enthusiastic about going to school and learning without hesitation. This can be understood as the combination of very well equipped facilities with teaching techniques and approaches that keep students interested in STEM fields. In terms of student STEM literacy, even though there are still questions about the difference NGS has made in terms of improving STEM subject literacy compared to non-STEM schools, students at NGS have acquired exceptional STEM literacy. Students at NGS get to enjoy more meaningful hands-on practices and experiences by participating in their PBL activities and active learning principles. This adds more value to their learning experiences. In addition, NGS students get to join various STEM related competitions and have won many medals for the school. Lastly, gender balance and participation in Cambodian STEM education is impressive. Female students get equal chances of participating as much as men. They also make significant contributions to their school by participating in STEM competitions with their male counterparts.

## Policy recommendations

The major concern involving the STEM education model, particularly for NGS, is the feasibility of it to fully scale up nationwide. As discussed in the synthesis section, the initiative of NGS is exceptional for being a STEM school. The model has been used to cultivate students' STEM interest and to significantly improve their STEM literacy. Not limited to that, NGS has also been effective in modernizing the Cambodian education system by introducing new teaching methods such as the students centered approach and transparental operating governance inside the school.

To make NGS schools feasible on a nationwide scale, a proper financial mechanism is required for long term sustainability. The current financial model of NGS is heavily dependent on government subsidies, specifically the MOYES. This applies to all NGS across the country. For the first three years of establishment, the MOYES is responsible for all of the NGS spending. After that time, the school uses a cost sharing mechanism to generate income which depends on the voluntary donations of parents for the school's development. This is not a practical and sustainable financial model for the long term. Initially, the ministry needs to restructure the sponsorship mechanism. Rather than set the donation in three-year periods, the MOYES should consider changing the sponsorship based on the amount of money needed for the area in which the school is located. As mentioned previously, each NGS does not have the same spending budget. NGS's in urban areas tend to have larger budgets than those located in the provinces. For example, 462USD is required at SSW NGS compared to 124USD for the NGS in Svay Rieng province. The MOYES should not limit financial support for an NGS in a rural area to only three years. Instead, the rural schools should receive financial support based on their specific needs. This will allow the school to sustain operations in the long run.

Cost sharing mechanisms for parents' voluntary contributions should be the main income generator for all NGS. However, not being limited to only one path, the school can use various mechanisms to generate income by considering the monthly rental of the school canteen to food vendors and private businesses, the rental of school spaces for night shift parking, renting school classrooms, or other resources. Also, NGS must remain open and welcome to all private donors who want to support the school. These are optional approaches that each school can use to further generate income in addition to the cost sharing mechanism. Moreover, the government should establish a

supporting program for poor families who cannot afford to make parental contributions by providing scholarships and subsidies, especially in the provinces and rural areas. However, it is important to note that this approach requires strong contributions from parents so it is necessary for them to fully acknowledge the advantages of a STEM education for their children and society.

## Conclusion

The research has found that access to a Cambodian STEM education is still limited as the number of STEM schools is still in short supply. However, their establishment is on the right track to move forward while making improvements. With its mission to modernize the education system, the NGS initiative is one of the first efforts of the Ministry of Education to reform and enhance its quality to improve human capital in the STEM fields. From interviews with the school principal and teachers, and the administration of closed end questionnaires with students, the major challenges have been identified. These include financial constraints, recruitment of qualified STEM teachers, and the difficulty in delivering the lessons using the new STEM approach. Overall, since its establishment, NGS has done brilliantly as a STEM school to promote modern methods of teaching, cultivate student interest and enhance their STEM literacy.

Questions remain on expanding this model to different regions and provinces across the country so that equal opportunity can be ensured for all citizens. Key limitations of this study were the measurement of NGS student understanding of STEM subjects, their literacy, monthly test performance and ability to solve basic exercises. This important data was not accessible at the time this research was conducted as it is not publicly available. These components would provide much valuable information to augment the current limited range of literature on Cambodia's STEM education. Future research could study the effects of the NGS teaching approach on student STEM literacy in comparison to those in the public schools. These results have not yet been proven

scientifically as regards the NGS effects on students' performance, specifically the STEM outcomes and literacy. Moreover, an in-depth study of the feasibility of the nationwide expansion of the NGS model is needed especially on the practical spending budget.

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# Appendix

**1. Semi Structured interview: School Principal**

Challenge:

- What do you see as the challenges that constrain the development of STEM education in Cambodia?
- Within your model, what do you see as the challenges to your school's implementation?
- Did your school face any difficulties during its establishment? Compared to the present, are the problems that you faced being solved?
- Did you find recruiting qualified teachers a problem? Why or why not?
- Regarding quality material and equipment, does your school face any challenges?

Curriculum

- What difficulties have you come across within that implementation?
- Do you replicate any other country's curriculum? Why or why not?
- What is the major goal and objective of your school? Have you successfully achieved any goals so far? Why/why not?

**2. Semi Structured interview question for teachers**

Challenge:

What difficulties do you face when trying to deliver the content of the lessons to the students?

- Do you find it difficult to understand the lessons in the curriculum?
- Is it hard to get students to understand the lessons?
- Regarding STEM teaching/learning materials, is it widely accessible and adequate? Why or why not?
- In terms of in-class activities, are the materials provided by the school sufficient?
- Regarding male and female students, do you notice any difference or is there any problem regarding gender balance or performance in your class?
- How about student behaviour? How do students behave in your class based on your observations?
- In terms of the challenges you have mentioned, what do you wish to change or think that could have been done better?

Curriculum

- Do you think that within the current curriculum, is it appropriate for students at this level? Why or why not?
- Given the current curriculum, what are the things that you think can be specifically improved?
- What do you think can be improved overall in terms of the current curriculum?

**3. Online, Self-completed Questionnaire for Students**

The purpose of this study is to find the current state of STEM education and the challenges of its implementation in Cambodia under the topic of "What is a successful STEM model in Cambodia?" This questionnaire asks your personal belief and preference toward STEM subjects and the model that you are currently studying. We, the 2019 Young Research Fellow team of Future Forum, are extremely grateful for any

information that may be provided. We are grateful for your time and assistance on this important research that will be used for the purpose of identifying the current stage of STEM education in Cambodia. Your participation is entirely voluntary and we would like to inform you that all of the personal information that you have provided here will be kept confidential and your answers will be used for the purpose of our research only.

**I. Attribute questions**

1. Age :
2. Sex

Male b. Female

3. Grade :
4. Contact information: Phone Number (optional):
5. How long have you been studying at this school?

a. less than a year b. 1 year c. 2 years d. More than 2 years

6. What motivates you to study at this school?

a. Self-interest/ Family persuasion b. Teacher's persuasion c. To realize my future goal d. Other:

7. How strong is your interest toward STEM (Science, Technology, Engineering, Math) in general?

a. Not interesting at all b. Less interesting c. Neutral d. Interesting e. Very interesting

8. "STEM skills are essential to a successful career." To what extent do you think this statement applies to you personally?

a. Strongly Disagree b. Disagree c. Neutral d. Agree e. Strong Agree

9. Do you get excited to go to your school?

a. Yes b. No

10. Why/ Why not? *

**II. Student interest**

a. Subject/Curriculum/classroom's environment/facilities

Please tick and complete the following based on your preference

To what degree do you find the following interesting?

11. Mathematics subject

a. Very interesting b. Interesting c. Neutral d. Less interesting e. Not interesting at all

12. Science subject

a. Very interesting b. Interesting c. Neutral d. Less interesting e. Not interesting at all

13. Engineering related contents

a. Very interesting b. Interesting c. Neutral d. Less interesting e. Not interesting at all

14. Technology related contents

a. Very interesting b. Interesting c. Neutral d. Less interesting e. Not interesting at all

15. Among the subjects/content mentioned above, which one is your favorite?
16. Why do you choose it as your favorite subject/content ?
17. Do you have a plan to pursue STEM related majors after you finish at this school?

a. Yes b. No

18. Why or Why not?

19. On a scale of 1 to 5, with 1 being the weakest and 5 being the strongest, Please tick the following charts based on your preferences. Note, You may only tick once per column:

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **How much do you enjoy studying the favourite subject you just listed above?** | | | | | |
| **How much do you enjoy studying the least favourite subject just listed above?** | | | | | |
| **How much do you enjoy studying at your school?** | | | | | |
| **How much do you enjoy in-class activities?** | | | | | |

20. Please tick on the following charts to indicate how satisfied you are with the following topic. You may only tick once per column.

| | **Very unsatisfied** | **Unsatisfied** | **Neutral** | **Satisfied** | **Very satisfied** |
|---|---|---|---|---|---|
| **Classroom setup** | | | | | |
| **Table and whiteboard (setup, light, fans/air con etc)** | | | | | |
| **Teachers** | | | | | |
| **Teaching Method** | | | | | |
| **Amount of In-class activities** | | | | | |
| **Content of In-class activities** | | | | | |
| **Duration of break times** | | | | | |
| **Study equipment** | | | | | |
| **Amount of Homework** | | | | | |
| **Laboratory** | | | | | |
| **Library** | | | | | |
| **Number of students in class** | | | | | |
| **Additional activities** | | | | | |

21. In class activities

Please tick the following based on your in class activities experience:

| | **Never** | **Rarely** | **Sometimes** | **Often** | **Always** |
|---|---|---|---|---|---|
| **Group discussion** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| **In class activities** | | | | | |
| **Group project** | | | | | |
| **Class experiments** | | | | | |
| **Computer classes** | | | | | |

22. Among the activities above, which one is your favorite? Why? *

23. Among the activities above, which one is your least favorite? Why?

b. Teacher's quality

24. To what degree, do you understand lessons that your teachers have explained?

a. Not at all b. To a small degree c. Neutral d. Understand well e. Understand very well

25. How do you rate the quality of your teacher's explanation?

Very poor 1 2 3 4 5 Very good

26. How do you rate the quality of the teaching method?.

Very poor 1 2 3 4 5 Very good

27. How often do teachers answer your questions?

a. Never b. Rarely c. Sometimes d. Usually e. Always

c. Material and equipment

28. How often do you visit the library? (please skip this question if your school does not have a library)

a. Never b. Rarely c. Sometimes d. Usually e. Always

29. Do you find your school library useful? (please skip this question if your school does not have a library)

a. Yes b. No

30. Does your school library have all the reading material that you need? ( please skip this question if your school does not have a library)

a. Yes b. No

31. How often do you visit the laboratory? ( please skip this question if your school does not have a laboratory)

a. Never b. Rarely c. Sometimes d. Usually e. Always

32. Do you find your school laboratory useful? ( please skip this question if your school does not have laboratory)

a. Yes b. No

**III. STEM Literacy**

33. To what degree do you feel confident with your STEM knowledge?

Very unconfident 1 2 3 4 5 Very confident

34. Compared to when you first start studying at your STEM school, have you noticed any change regarding your understanding of STEM?

a. Yes b. No c. I have not really noticed that

35. What is the subject that you feel most confident about in terms of knowledge?

a. Science b. Technology c. Biology d. Chemistry Physic

36. Have you applied the concepts and disciplines that you learn in school into practice in real life?

a. Yes b. No c. I do not really notice that

37. If yes, what did you do? List one or two examples of real life practice where you have applied the concept that you have learned in school.

38. If no, what constrained the practice?

39. Do you think the content and curriculum in your current school is appropriate and fits students at your level? Why/ Why not?

40. Please tick the following subjects based on your ability to solve and complete the test with 1 being the easiest and 5 being the hardest.

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **Math test** | | | | | |
| **Science test** | | | | | |
| **Engineering test** | | | | | |
| **Technology test** | | | | | |

41. After learning in your current school, Do you feel confident with your STEM literacy to further choose STEM related fields as your future career?

a. Yes b. No c. I have never thought about that

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