Ministry of Education, Youth and Sport
Department of Policy

Article

Improved STEM Education in Cambodia through Spatial Analysis of Secondary Resource Schools

Un Sreynet[*1], Sin Navy[2], Chhim Rithivong[3]

*[*123]Department of Policy, Ministry of Education, Youth and Sport, Cambodia, Corresponding author's email: sreynetun@gmail.com*

Received: April, 2021/ Accepted: May, 2021

Abstract

In Cambodia, the establishment of the secondary resource schools has played a very important role in promoting STEM education. In this article, we aim to determine approaches to enhance STEM education in Cambodia through spatial analysis for appropriate locations of secondary resource schools. This paper, in particular, focuses on contribution of resource for promoting STEM education, spatial distribution of secondary resource schools, appropriate location for secondary resource schools, as well as problems and constraints in managing the secondary resource schools. This study relies primarily on qualitative data, however, it was substantiated by quantitative information. The research design includes case study, social and participatory approaches for collecting qualitative data and information. Moreover, raw data from secondary sources were also collected for statistical analysis to compare with qualitative findings. In addition, Measure Distance Map App was also used to collect latitude and longitude data on each school location for the spatial analysis. In our detailed study in Kampong Thom, Kratie, Kep, Banteay Meanchey and Phnom Penh we found that: establishment of the secondary resource schools has contributed in a promotion of STEM; despite that. school networks were not sufficiently beneficial due to insufficient transportation cost, limited capacity; weak operation and management is a continuing challenge. (1) The research confirms that the number of secondary resource schools was passively and strongly correlated to the number of students, the number of secondary schools, and the number of network schools. (2) An average distance between secondary resource schools and network

schools was 4.2 kilometers, ranging from 2.0 to 9.4 kilometers; it was the furthest in Kratie and the nearest in Banteay Meanchey. (3) The spatial analysis reveals that the existing secondary resource schools are not central which leads to difficulty of access by network schools. (5) Samdach Ov or Serey Sophoan Upper Secondary Schools for Banteay Meanchey as well as Boeng Trabek Upper Secondary School and Santhor Muk Upper Secondary for Phnom Penh are likely to optimize the distance between the secondary resource schools and school networks for future construction. () There are four key problems or constraints which limit the impact of the secondary resource schools. They include social norms, capacity, operation, and management.

***Keywords*:** Science; technology; science, technology, engineering and math engineering and mathematics (STEM); spatial analysis; secondary resource schools; Cambodia

To cite this article: Un, S., Sin, N., & Chhim, R. (2021). Improved STEM Education in Cambodia through Spatial Analysis of Secondary Resource Schools. *Cambodia Education Review, 4*(1), 52-86.

1. Introduction

In 2015, STEM (Science, Technology, Engineering and Mathematics) was introduced when the First Cambodia's Science & Engineering Festival (CSEF) was organized with the impressive attendance of 10,000 people.[2] Moreover, the Industrial Development Policy of Cambodia (2015-2025) has prioritized STEM as a multi-dimensional strategy in preparing the students of today to become successful individuals of tomorrow with a focus of science and mathematics education (CDC, 2015; MoEYS, 2016). It is a fact that STEM education addresses the practical application of knowledge to real-world problems for economic growth and social development based on creativity, problem-solving, and critical thinking (Machuve & Mkenda, 2019). As the result, STEM has supports the increasing demand for skills needed for adapting to the fourth industrial revolution (Armbrecht, 2016) and for generating economic growth (Engler, 2012, Kaing, 2016). According to Pimthong and Williams (2018), each discipline of STEM does not exist alone, but, they are interrelated as complex and multidimensional problems combine different elements. An integration of STEM concepts and

[2] See detail at http://www.stemcambodia.ngo/

processes among young people through participation in multidisciplinary situations help to prepare people for their future life and for the workforce (English, 2017).

Cambodia has prioritized STEM for supporting economic growth and social development. In 2015, Cambodia has been re-classified as a lower-middle-income economy by the World Bank Group, as its Gross Net Income (GNI) per capita was had reached $1,070 (World Bank, 2016). A strong institutional support of the Royal Government of Cambodia through the Ministry of Education Youth and Sport (MoEYS) is clearly described in the Teacher Policy Action Plan (2015-2020). In 2015, the MoEYS set out that all teachers will have at least a Bachelor's degree by 2020 to ensure their capacity to educate the next generation of professionals (Blanquat & Associates, 2016). In promoting STEM education, the MoEYS has worked at various levels to formulate school streams: science vs. social science (Kao 2013). At the same time, the necessary infrastructure and resources are being equipped at secondary schools and at universities for students to support majors in the fields of STEM (MOEYS, 2018). Education is also necessary to support the country in achieving its ambition to transition from a lower-middle income country to being an upper-middle income country by 2030, and to a developed country by 2050 (MoEYS, 2014). As clearly stated in the government's strategy, STEM education is aimed at strengthening sectors which require skilled labor among young learners and professionals (Blanquat & Associates, 2016). As one of the 10 country members in the Association of Southeast Asian Nations (ASEAN), Cambodia is striving to expand employment markets for young Cambodians to be at an advantage in the ASEAN Economic Community through access to STEM careers, and to reduce its economic dependency on the garment and tourism sectors (Anonymous, 2015).

In general, science and mathematics education are delivered from primary to secondary schools worldwide, but in the engineering field of study they are included at higher education (Holmlund et al., 2018). While technology courses are provided by vocational education, it is also somewhat included at the secondary level (National Science Board, 2015). In recent years, teachers at secondary schools have engaged in innovative new approaches and include more STEM education in their classrooms. As a result, the higher quality of science education at the secondary level contributes to developing scientific literacy and understanding which enables students to pursue sciences and engineering at the university level. In the other word, generating higher levels of participation in science-related studies at university is associated with the improvement of science education at secondary schools (Ainley et al., 2008). However, even though STEM education has been integrated into the school curriculum from the primary to the secondary level, there are still many constraints in promoting STEM literacy.

Those challenges include insufficient content integrated into national curriculums, lack of resources and facilities, insufficient competent teaching staff for science and engineering, and the perception of students that the subjects are too difficult. According to the Ministry of Education Youth and Sport (MoEYS) in 2015, instruction in science, math, and technology was provided at the secondary level, but a nation-wide required curriculum did not exist.

For example, the lack of engineering concepts in the secondary school curriculum may be a contributing factor to the low rates of students pursuing study in this field. Among countries in ASEAN, the low number of students enrolling in the engineering field of study in Cambodia has become a noted concern in this region (ASEAN Secretariat, 2007). Moreover, secondary schools are faced with a lack of facilities, resources, and qualified teachers to support STEM education, which is needed to be aligned with regional and international standards for curriculum and instructional practices (USAID, 2010). Students perceive STEM education include difficult subjects because there were few opportunities for students to engage in practical application and experimentation. Today, there are too many business graduates, creating a surplus of job seekers in that sector, and while STEM sectors do not have sufficient human resources (Kaing, 2016). Currently, improvements in the availability of resources, experimentation, and teaching methods have not yet attracted students or improved their understanding or performance in STEM-related studies (Recayi et al., 2012).

According to Goldstone & Sakamoto (2003), the world has become a complex place and scientific problems need abstract reasoning about systems to appreciate their intricacies. Sme education specialists have argued that students at the secondary level require opportunities to engage in laboratory experiments and scientific investigations (Achieve, Inc., 2013). At secondary schools, laboratory practice is crucial (Luft et al., 2011) because students are involved in improving scientific skills (Suleiman, 2013), communicating their ideas to others (NRC, 1996), and establishing the accuracy of their beliefs (Angus & Keith, 1992). Teaching methods in the classroom alone are not enough, as the improvement of student understanding and recollection of information through experimentation and practice help developing problem-solving and critical thinking skills (Kigali Institute of Education, 2011). Moreover, the provision of the necessary equipment for experiments and practical activities in science must be aligned with the daily life of the students (Ogunmade, 2005). Under the supervision of teachers, the experiments and demonstrations are carried out by the students by applying theoretical knowledge with practical activities done in the laboratory, classroom, and field work (Tytler, 2007). Sandifer & Haines (2009) have found that hands-on activities are the best strategy for effective science teaching and learning.

The Global Competitiveness Report 2017–2018 concluded that the quality of math and science education in Cambodia is ranked at 111 out of 124 countries. During his first mandate, the Minister of Education H.E. Dr. Hang Choun-Naron has made significant advances in educational development. The establishment of secondary resource schools has been one of his efforts aimed at delivering well-rounded education services to the communities. In early 2011, the Asian Development Bank (ADB) funded the Education Sector Development Project II (ESDP II) which included the construction of 18 secondary resource schools in Cambodia. Today, 50 secondary resource schools have been constructed throughout the country and each secondary resource school is part of a network of up to eight secondary schools for the purpose of sharing resources. A purpose of the project is to improve quality and equity of education in Cambodia with more effective secondary education, improved teacher competency, and stronger education management practices. In aiming to make secondary resource school to be sites for increased learning and teaching resources, they are equipped with computer labs, libraries, science labs, meeting rooms, and a teachers' room. In particular, secondary resource schools have played very important roles in promoting STEM education by providing the opportunity for students to engage in experiments and practical work linking theories learned in the classroom and real-world applications.[3] Accordingly, this paper aims explore to approaches to enhance STEM education in Cambodia through doing spatial analysis for the location of secondary resource schools by focusing on spatial distribution of secondary resource schools, appropriate location for secondary resource schools, and problems and constraints in the management of secondary resource schools.

[3] See details at https://moeys.gov.kh/images/moeys/Projects/259/SRC%20Brochure-Eng.pdf

2. Research methodology and secondary resource school

This study employs both exploratory research and descriptive research methods to examine the research questions. This study relies primarily on qualitative data, however, it was substantiated by quantitative information. The research design includes case study, social and participatory approaches for collecting qualitative data and information. Moreover, raw data from secondary sources were also collected for statistical analysis to compare with qualitative findings. In addition, Measure Distance Map App was also used to collect latitude and longitude data on each school location for the spatial analysis. During the field work, semi-structured questionnaires were applied to collecting qualitative data from school management teams at host secondary resource schools and the schools' networks in Kampong Thom, Kratie, Kep, Banteay Meanchey and Phnom Penh. In each study province, one secondary resource school and three network schools (at least) were selected for the interview (Table 1). The interview focused upon how secondary resource schools are located, operated, and managed. In addition, the interviews also investigated how secondary resource schools are beneficial to STEM education in the host school and school network. Key informant interviews were made by using an unstructured questionnaire to collect qualitative data from the Ministry of Education Youth and Sport, and the Provincial Department of Education Youth and Sport. The interviews were held, as well, to explore possibilities for policy and program intervention regarding to the management of secondary resource schools. Ultimately, the interviews helped to understand better the role of the MoEYS in supporting the operation and management of the secondary resource schools at national and sub-national levels.

Both quantitative and qualitative analyses were applied. They included desk review and problem analysis. Desk review is an important part of the assessment by collecting, organizing and synthesizing available reports and previous publicaton. This enabled the researcher to gain an understanding of the context involved and results produced in the operation of secondary resource schools. The desk review also helped to identify problems and obstacles faced by the secondary resource schools. Problem and situation analysis facilitated exploration of the general position or context in which the secondary resource schools and networks operated. The findings elicited from using this technique provided the contextual knowledge needed for assessing the management of secondary resource schools.

Table 1

List of respondents for in-depth interviews and key informant interviews

No.	Institution		No.
	Unstructured questionnaire for key informants		
1	Ministry of Education Youth and Sport	General Secondary Education Department	1
2	Provincial Department of Education Youth and Sport in Banteay Meanchey	Provincial Office	1
3	Provincial Department of Education Youth and Sport in Phnom Penh	Provincial Office	1
	Semi-structured questionnaire for in-depth interviews		
4	Provincial Department of Education Youth and Sport in Kampong Thom	Provincial Office	1
5	Porng Tek Lower Secondary School	Management team	1
6	Hun Sen Krong Kep Lower Secondary School	Management team	1
7	Bun Rany Hun Sen Chakriya Vong Upper Secondary School	Management team	1
8	Hun Sen Chamkar Dong Upper Secondary School	Management team	1
9	Hun Sen Khlar Koun Upper Secondary School	Management team	1
10	Tek Thlar Lower Secondary School	Management team	1
11	Sandech Ov Upper Secondary School	Management team	1
12	Serey Sorphorn Upper Secondary School	Management team	1
13	Chbar Ampeouv Upper Secondary School	Management team	1
14	Hun Sen Prek Pra Lower Secondary School	Management team	1
15	Bun Rany Hun Sen Phsardeounthkov Upper Secondary School	Management team	1
16	On Chanh Lower Secondary School	Management team	1
17	Kratie Krong Upper Secondary School	Management team	1
18	Damrei Chorn Khlar Lower Secondary School	Management team	1

19	Hun Sen Balang Upper Secondary School	Management team	1
20	Stung Sen Upper Secondary School	Management team	1
21	Panha Chi Lower Secondary School	Management team	1

In the quantitative analysis, ANOVA was used to test whether there was significant difference between the mean distance between secondary resource schools and network schools in the five study areas. The correlation analysis was used to test the association of numeric variables between the number of resource schools, number of secondary schools, and number of network schools. ArcView software was applied to map secondary resource schools and school networks in Cambodia and to explore the best location for resource schools in Banteay Meanchey and Phnom Penh.

In 2004, the MoEYS received loans from the ADB to implement the Second Education Sector Development Project (ESDP II). The project was implemented between 2004 and 2008 in order to enhance equitable access to education by improving the quality of lower and upper secondary education and providing demand driven community-based skill training opportunities, primarily for out-of-school youth in under-resourced areas. The project completed 18 of the 24 originally planned upper secondary resource schools, and equipped them with science and computer facilities. Moreover, the MoEYS delivered multi-day training sessions for 243 science teachers, and a separate secondary resource school management workshop for provincial directors, school directors, and task force members. Consequently, before project completetion, it was not possible to properly evaluate SRC operations and provide adequate oversight. This has had an impact on management efficiency, and ultimately limited student access to quality science teaching (ABD, 2012). After completion of the ESDP II, the Enhancing Education Quality Project (EEQP), carried out between 2008 and 2014, was designed to make substantial improvements in the quality and efficiency of the secondary education sector. The overriding objective was to strengthen the capacity of the agencies responsible for the delivery of quality education. The project was completed with a successful assessment which utilized the ratings of highly relevant, effective, efficient, and partly sustainable. Under the EEQP, 18 secondary resource schools were built.[4]

The project helped to improve school capacity management, to increase school outcomes, to develop a teacher policy which will have an ongoing impact, to maintain functional MIS, to

[4] See detail: http://www.moeys.gov.kh/en/eeqp/tu-3-strengthening-secondary-education/secondary-resource-centers.html#.Xj7XCWgzY2w

create quality control systems in TTCs and schools, to conduct training in ICT and multimedia, to establish multimedia center for the NIE, to improve the safety and security of facilities, particularly for women, to significantly improved teaching and learning facilities, and to enhance assessment techniques, textbooks and teacher guides. But, it was less successful in sustaining the full capacity of use by the SRC and this will need to be achieved over time. The project also undertook many additional tasks to enable the ESDPII, with SRCs to be incorporated into the implementation plans for the EEQP (MoEYS, 2015). According to the Asian Development Bank, the proposed Second Upper Secondary Education Sector Development Program (USESDP 2) is part of the phased support of the ADB for the development of high-quality human resources by improving the effectiveness of upper secondary education (USE). The USESDP 2 builds on and complements ADB's ongoing Upper Secondary Education Sector Development Program (USESDP 1). The program will (i) improve teacher quality and boost the quality and labor market relevance of USE; and (ii) strengthen institutional capacity for USE planning, management, and delivery. While the resulting policy reforms will apply nationwide, the project activities will cover only selected areas.

3. Results and findings

3.1. Contribution of secondary resource schools in promoting STEM education

In 2004, secondary resource schools were initiated by the MoEYS and the Asian Development Bank (ADB). Construction and operation of secondary resource schools has been funded by the ABD in three different projects aiming to improve the quality of secondary education through building educational facilities. The projects include the Second Education Sector Development Project (ESDP II), the Enhancing Education Quality Project (EEQP), and the Upper Secondary Education Sector Development Program (USESDP).

Under the ESDPII (2004−2008) project, 18 resource schools were constructed and labelled Secondary Resource Centers. The main purpose of the project was to increase resource mobilization for the education sector by constructing 24 model school buildings for teacher development in the fields of Science, Math, and Information Communication Technology. In order to establish resource schools across the country, the ADB provided further funds under the EEQP (2008-2014) to construct another 18 secondary resource schools in Cambodia. This project primarily focused on education system management, teacher professional development, and enhancing secondary education. Between 2016 and 2021, the ADB funded 14 more

secondary resource schools under the USESDP project. The project was targeted to improve the quality of human resources at the upper secondary education level, needed for sustaining Cambodia's economic growth and social development. By the end of December 2019, there were 50 resource schools functioning in Cambodia (Figure 1).

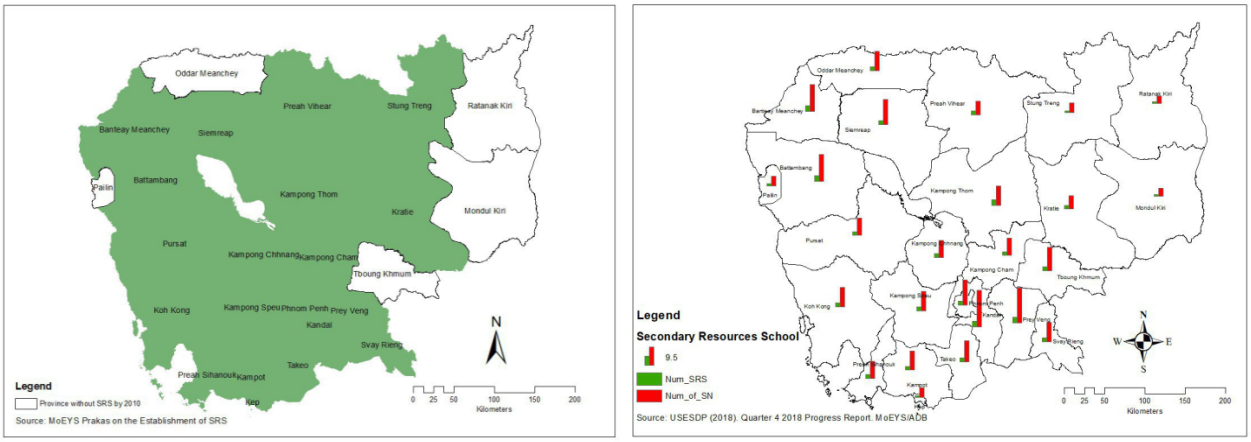

***Figure 1*:** Mapping secondary resource school and school networks in Cambodia

Today, secondary resource schools are in operation in all the 25 provinces and cities across the country, with the number in different provinces varying due to demand and the availability of funds from ADB. On average, two resource schools were established in each province or the capital city, with a maximum of 3 and a minimum of 1. While provinces such as Banteay Meanchey, Battambang, Kampong Thom, Kandal, and Prey Veng, host up to three secondary resource schools, ADB only provided for one secondary resource school in the provinces of Mondulkiri, Kep, Pailin, Ratanakiri, and Stung Treng. Other provinces each host two secondary resource schools. The research, using correlation analysis illustrated in Figure 1, found that the number of resource schools was positively and strongly correlated to the number of students (P-value=0.000), to the number of secondary schools (P-value=0.000), and to the number of network schools (P-value=0.000). On the basis of these findings, it can be confirmed that the construction of secondary resource schools in Cambodia directly responded to the real needs of students at host schools and school network institutions, for the promotion of STEM education. The higher number of students and secondary schools reflects the higher number of secondary resource schools established.

According to the Department of Secondary Schools at the MoEYS, the secondary resource schools have been established to increase the opportunity for access to experimentation and practice in the sciences. The secondary resource schools have been established in a city center or provincial town. Each secondary resource school covers several upper secondary or lower secondary schools within 20 kilometers to the east, west, north and south. Teachers and student

at the network schools are able to access facilities of the secondary resource school for the purpose of doing experiments and practical learning [Pers. Comm. MoEYS]. The host schools have been funded with the annual budget for operation of the secondary resource schools, as well as the purchase of materials and equipment, and, a scholarship scheme for poor students. However, students and teachers at school networks only receive budget resources to cover their transportation and the purchase of materials and equipment.

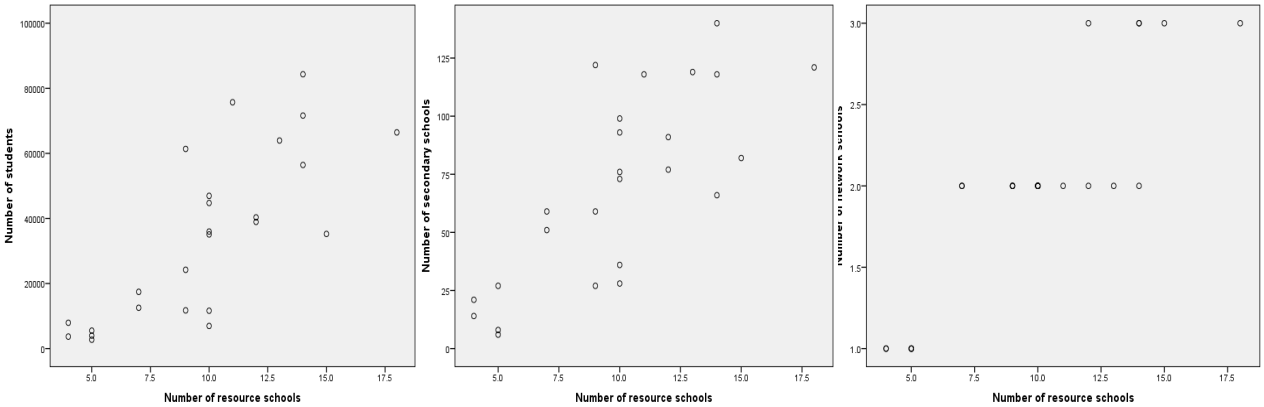

Figure 1: Association among resource schools, secondary schools and network schools

R^2= 0.777, P-value = 0.000 R^2= 0.763, P-value = 0.000 R^2= 0.880, P-value = 0.000

The interviewee, from the interview of a staff member at Chbar Ampeouv Upper Secondary School, revealed that: "My school has received around 35 million Cambodian Riel per year to pay for water, electricity, equipment and renovation of the infrastructure. As I know the funding was previously from ADB. From this year, it is now allocated by the MoEYS under Public Budget (PB). I get additional 5 million Cambodian riel, so it is now a total of 40 million Cambodian Riel." [Pers. Comm. Chbar Ampeouv USS]. Since 2019, the MoEYS has allocated the annual budget for operation of secondary resource schools, after completion of the EEQP project. To increase the use of secondary resource schools, the USESDP is designed to provide an annual budget for transportation and purchases of materials and equipment. Both host schools and network schools are now annually funded with 500 US dollars to pay for transportation of teachers and students, and to buy chemicals required for their experiments at resource schools [Pers. Comm. MoEYS]. A school principal expressed that:

> 'I think the secondary resource school is very useful because it gives an opportunity to my students to do experiments and to practice in earth science, physics and biology. Through MoEYS, ADB are funding my school with 500 US dollars. The amount may be very small for

> other schools but it is a lot for my school. With that support, I can bring my students to practice at Hun Sen Khlar Koum secondary resource school 10 times per year. I think other schools can do only between 4 and 6 times. I spend more on transportation cost than the purchase of experiment materials or chemicals because the available budget is not enough. Also, experiment equipment or materials are not available around my school.' [Pers. Comm. Serey Sorphorn USS]

In principle, a secondary resource school functions with support of four staff: one staff for the laboratory, two staff for Information Technology (IT), and two contract staff to support other work required at the secondary resource school. The building has facilities and equipment to promote STEM education for the host schools and the network schools, especially physics, chemistry, earth science and biology [Pers. Comm. PDoEYD in Phnom Penh]. The operation of resource schools across Cambodia has been very beneficial for students at secondary schools when they enroll at university. Students are familiar with the courses from the experience with experimentation and practice found at the secondary resource schools. As the result, the Ministry has gained more positive feedback from students and parents because students are able to use resource schools to get clearer understanding of theories learned in the classroom. In addition, students from poor families have also been provided scholarship to support their studies [Pers. Comm. MoEYS]. Under the USESDP project, the ADB has agreed to provide scholarships for students, with each secondary resource school being granted 15 scholarships. A student receives 200 US dollars per year for a period of 2 years. This academic year (2019-2020) was the third year of the arrangement [Pers. Comm. PDoEYD in Phnom Penh]. To date, the MoEYS has considered establishment of secondary resource schools as the most cost-effective strategy to promote STEM education at secondary school level in Cambodia. It is a fact that the MoEYS is not able to equip laboratories, computer labs and libraries at all secondary schools across the country. One respondent pointed out: "Only the cost of renovating a classroom for a laboratory is roughly 60,000 US dollars and it does not include the equipment and facilities. How can the Ministry invest in laboratories of the school. For example some schools in remote areas have only fewstudents enrolling at secondary level. They must use the facilities and equipment available at the secondary resource school." [Pers. Comm. MoEYS]. "At the same time, parents of students at Kratie Krong Upper Secondary School applauded the school and were optimistic about its impact. The schools in the rural areas now have modern computer labs, laboratories and libraries for students to practice." [Pers. Comm. Kratie Krong USS].

3.2. Spatial distribution of secondary resource schools

There are specific criteria for selecting a school to be a secondary resource school. First, the school must be located in the center of the city or province. Second, there must be sufficient teachers to be responsible for all subjects. The third and fourth criteria are that the school must be equipped with utilities such as electricity and water. The fifth and sixth criteria are that the school is strongly supported by the community and has good management. Having sufficient land for the development is the last criteria. [Pers. Comm. MoEYS] When all the schools wish to establish a laboratory at their own location, bias or jealousy about the selection of secondary resource schools cannot be avoided. The officer at the Department of Secondary Schools explained: "I used to get reactions and complaints on social media by teachers at remote schools about the location selection of secondary resource schools. They are not happy and feel that we [the Ministry] have abandoned the promotion of science in remote schools. During the interview, the offer at the MoEYS also explained that it is not yet now cost effective to locate a secondary resource school in remote areas because of the low number of students the laboratory equipment is not fully used [Pers. Comm. MoEYS] . 'In Kep, the secondary resource school hosted by Hun Sen Chamkar Dong Upper Secondary School has supported around 1,000 students to do experiment and practice. The secondary resource school has a computer lab, laboratories, a library and a place for students and teacher to do group learning activities to upgrade their understanding of science [Pers. Comm. Hun Sen Chamkar Dong UPP]. During the field work, school principals provided different reasons why their schools were selected to host a secondary resource school. One stated:

> 'Compared to other schools, Hun Sen Khlar Koun Upper Secondary has the best location. My school is near the Provincial Department of Education and have a comfortable campus for building a secondary resource school. I don't think other schools here have enough space to build this center like us.' [Pers. Comm. Hun Sen Khlar Koun USS]

While the school principal at Hun Sen Khlar Koun Upper held that it had the best location and a large campus, it was quite hard for the school principal in Banteay Meanchey to suggest the best location to be conveniently accessible by all network schools. For example, there are four upper secondary schools in this province: Samdech Ov, Serey Sorphorn, Hun Sen Khlar Koun, and O Ambel. I do not see any other good location in this province to be allocated for another secondary resource school. If it is located at Serey Sorphorn Upper Secondary School, the campus is a bit small. But it is good to be at Serey Sorphorn Upper Secondary School

because the school includes all levels, from primary to upper secondary" [Pers. Comm. Sandech Ov USS]. Similarly, the school principal at Hun Sen Chamkar Dong Upper Secondary School did not agree that the best location should be the sole criteria for the selection of the host school for the SRS in Kep province.

> The main reason for selecting this school as a secondary resource school is that it was, at the time, the only upper secondary school available in town. Also, our school has a big campus. Moreover, the school had the highest number of students enrolled at that time. We have five network schools. They are coming to use our secondary resource school. [Pers. Comm. Hun Sen Chamkar Dong UPP]

In Kampong Thom, Hun Sen Balang Upper Secondary School was the most outstanding in terms of national examination results at the upper secondary level, student performance, and enforcement of morality. At first the plan was that this school would host the New Generation School (NGS) but it was later chosen to be the site of a secondary resource school. The MoEYS ascertained that Hun Sen Balang Upper Secondary School did not yet fulfill the criteria to host the NGS program [Pers. Comm. Hun Sen Balang USS]. The equipment and facilities available at secondary resource schools are managed by host schools, but they are shared for use by network schools. The network schools prepared schedules for bringing students to practice and to do experiments at the laboratories set up at the secondary resource schools.

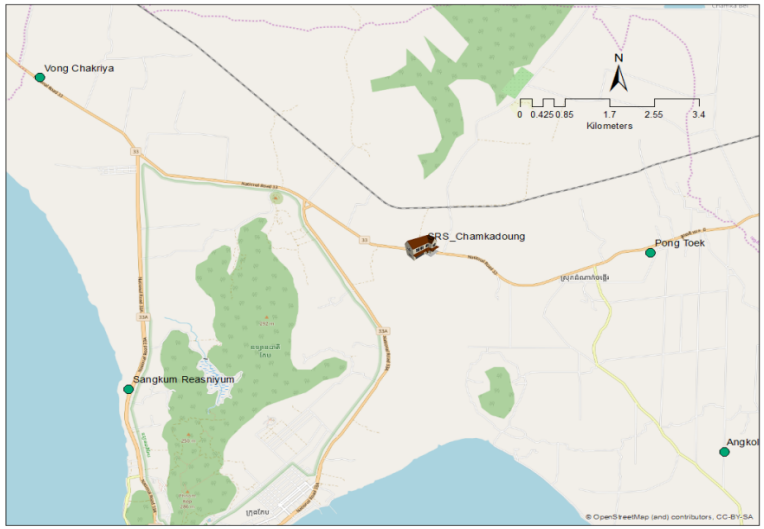

Figure 2. Location of resource school in Kep

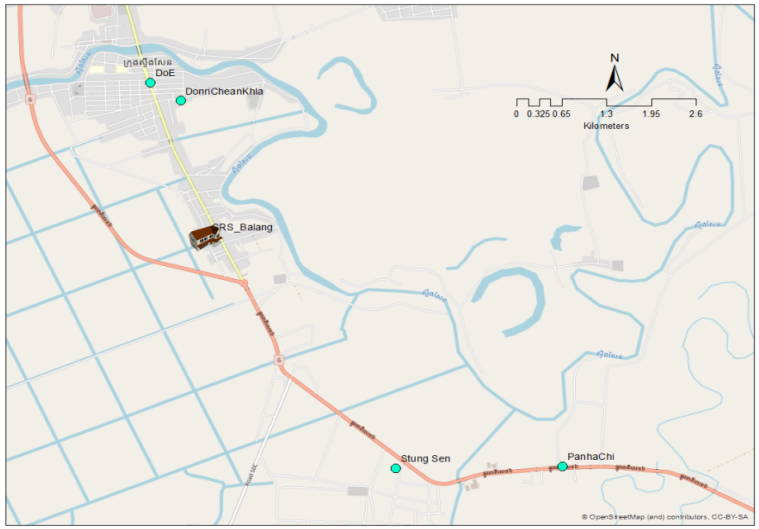

Figure 3. Location of resource school in Kampong Thom

Figure 4. Location of resource school in Kratie

Figure 5. Location of resource school in Banteay Meanchey

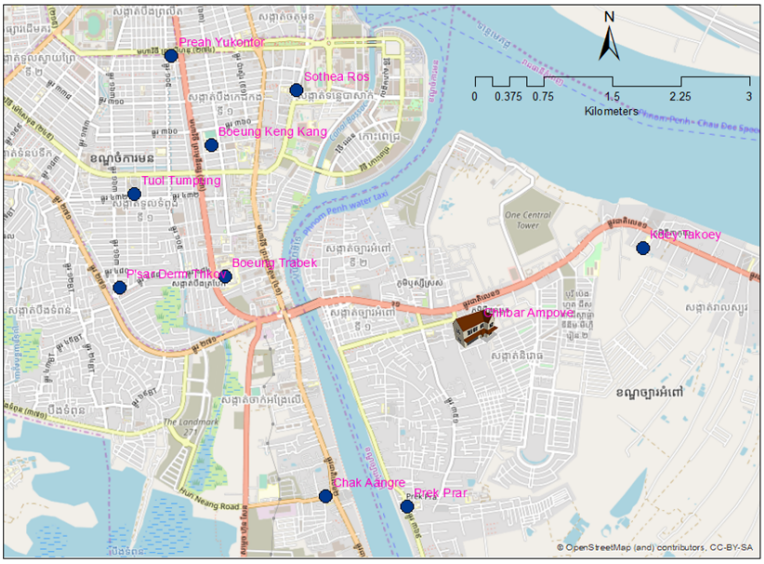

Figure 6. Location of resource school in Phnom Penh

According to spatial analysis of the existing secondary resource schools in Kampong Thom, Kratie, Kep, Banteay Meanchey and Phnom Penh, there are some challenges related to the distance between secondary resource schools and network schools (see Figures 2-5). However secondary resource schools are mainly located in provincial or city centers, resulting in many schools with limited access because of the far distance. At the same time, all of the network school officials expressed the desire to have their own laboratories. Network schools in remote areas did not have the means to transport their students to the secondary resource schools. Moreover, secondary resource school equipment/facilities tended to already be in full use by the host schools. [Pers. Comm. MoEYS] Figure 6 illustrates the average distance from the secondary resource schools to network schools was 4.2 kilometers, with individual distances ranging from 2.0 and 9.4 kilometers. According to ANOVA test results, Kratie was the furthest (7.1 kilometers) and Banteay Meanchey was the nearest (2.8 kilometers) (P-value = 0.000). In Kratie, there was one secondary resource school called Kratie Krong Upper Secondary School and it had only two network schools (On Chanh Lower Secondary School and Ka Po Lower Secondary School). On Chanh Lower Secondary School is located 9.4 kilometers away from Kratie Krong Upper Secondary School, and the distance of Ka Po Lower Secondary School to the resource school is 4.9 kilometers.

The distance from Hun Sen Chamkar Dong Upper Secondary School to its network schools[5] makes it fairly central. Given that, it is unlikely that the furthest school would find it very hard

[5] Sangkum Reas Niyum Lower Secondary School, Hun Sen Krong Kep Lower Secondary School, Bun Rany Hun Sen Chakriya Vong Upper Secondary School, Porng Tek Lower Secondary School, and Hun Sen Angkor Lower Secondary School

to take students to the secondary resource school, and they would still have most of the morning or afternoon session to use for their experiments. The average distance to secondary resource schools is as far as 6.0 kilometers; it was up to 7.8 kilometers for Bun Rany Hun Sen Chakriya Vong Upper Secondary School and 7.1 kilometers for Hun Sen Angkor Lower Secondary School. The school principal at Hun Sen Krong Kep Lower Secondary School pointed to both advantages and disadvantages in sending students to the secondary resource school. The students are able to do experiments and practice what they have learn from theories, but it is not safe for students to travel far from home [Pers. Comm. Hun Sen Krong Kep LSS]. Similarly, the school principal at Bun Rany Hun Sen Chakriya Vong Upper Secondary School raised concerns about the distance and the fact that students are required to find their own transportation to the secondary resource school. He emphasized that the school cannot be responsible for any incidents which befall students and/or teachers during their travel. The school principal complained: "it is waste a lot of time to travel to the secondary resource school. We still need to bring our own equipment, materials and chemicals. So why do we need to go to resource school? and why don't we have a room for it at our school?" [Pers. Comm. Bun Rany Hun Sen Chakriya Vong USS]

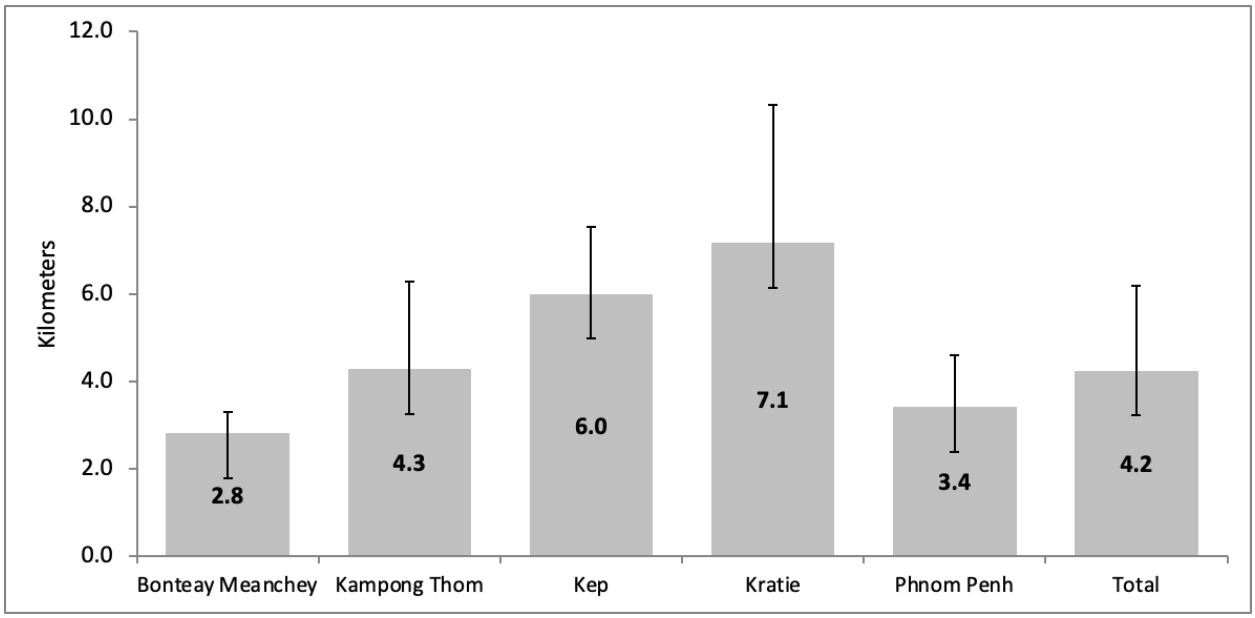

Figure 7. Mean distance to resource schools

Note: P-value = 0.000 of ANOVA among the five geographical areas, and P-value = 0.000 of T-test for average distance of 10 kilometers.

For Kampong Thom, the location of Hun Sen Balang Upper Secondary School is best suited for the SRS, but, there means a challenge for Pangha Chi Lower Secondary School. That school is located as far as 8 kilometers away from the secondary resource school. Damrei Chorn Khlar Lower Secondary School had the best access location for network schools compared to the other two options. The distance from Damrei Chorn Khlar Lower Secondary School to Hun Sen Balang Upper Secondary School is only 2.15 kilometers. As a result, the school principal at Pangha Chi Lower Secondary School was very satisfied secondary resource school. After having opportunity to do experiments, the performance of students improved [Pers. Comm. Panha Chi LSS]. In contrast, the school principle at Damrei Chorn Khlar Lower Secondary School identified the high risk of the long travel needed by students to make the trip to the secondary resource school. The principal clarified: "I do not think it is worth it to send my students to the secondary resource school because there are insufficient facilities and equipment for students and teachers to use. It is not very easy to bring our students to use facilities at other schools. When we arrive at the resource school, the people in charge are not there. It is also such a waste of time and money to spend on transportation with little results from practice and experiments. If we do it at our school, we can make better quality experiments and practice.' [Pers. Comm. Damrei Chorn Khlar LSS]. The Provincial Department of Education, Youth, and Sport shared a similar view that: "it is not so effective because of late arrival of either students, teachers, or the people in charge of the laboratory. At the same time, some students missed the session because of various reasons such as no transportation or laziness." [Pers. Comm. PDoEYD in Kampong Thom]

Among all the five geographical areas, the average distance between the secondary resource school and network schools in Kratie (7.1 kilometers) was the furthest, as shown in Figure 6. At Kratie Krong Upper Secondary School, parents were delighted that their children have the chance to study at a school where laboratories, a computer lab, and the library are well equipped. More and more parents are sending their children to study at Kratie Krong Upper Secondary School because students can practice after learning in the classroom. Some students from nearby districts also transferred to this school because they want to have better quality of education. [Pers. Comm. Kratie Krong USS] As the location of On Chanh Lower Secondary School is as far as 9.4 kilometers away from the secondary resource school, students had little opportunity to take part in doing experiments and practical learning. With the support from the MoEYS in the amount of 500 US dollars per year, the school is able to send students to the secondary resource school around 5 or 6 times per year. The distance from On Chanh Lower

Secondary School to resource school was quite far and hard for transportation [Pers. Comm. On Chanh LSS]

The average distances of the secondary resource schools were the shortest in Phnom Penh (2.8 kilometers) and Banteay Meanchey (3.4 kilometers) (see Figure 6 and Figure 5). In Banteay Meanchey, the Hun Sen Khla Koun Upper Secondary School is in the urban center. Therefore, it is not very far from the rest of the network schools. For Chbar Ampov Upper Secondary School, the school was located in central of Phnom Penh; but, some users still found it hard to commute to the secondary resource school, especially for those from Preah Yukuthor Upper Secondary School. There are three resource schools in Phnom Penh, but only two in operation, Hun Sen Champouvorn Upper Secondary School and Chbar Ampeouv Upper Secondary School. The resource school at Entrak Tevy High School is under construction and it is not yet operating [Pers. Comm. Chbar Ampeouv USS]. The new construction is expanding the coverage of network schools in Phnom Penh. The school principal at Chbar Ampeouv Upper Secondary School welcomed all students, teachers and researchers per request to use the secondary resource school for the purpose of study and research. Some private schools and local NGOs also used the resource school for doing experiments and organizing meetings [Pers. Comm. Chbar Ampeouv USS]. With space for construction of a laboratory at Hun Sen Prek Pra Lower Secondary School [Pers. Comm. Hun Sen Prek Pra LSS] and no resource for construction of a laboratory at Tek Thlar Lower Secondary school [Pers. Comm. Tek Thlar LSS], the available secondary resource institution has provided a long-term support to many such secondary schools because they did not have space for construction of their own facilities.

3.3. Appropriate location for secondary resource schools

The available public budget for education in Cambodian remains as low as 5.5 US dollars per capita per year. The figure is very low if compared to its neighboring Vietnam which expends 90 US dollars per capita per year. In promoting STEM education, facilities are very important because all science subjects require doing experiment and practice. Due to limited government budget resources, construction of laboratories and facilities/equipment for experimentation at all secondary schools in Cambodia is very challenging. the construction of more lower secondary in selected city or provincial center would remain a choice even in the next 10 years. The Ministry has no sufficient budget to construct laboratories at all the school across the county. However the distance of network school coverage is likely to gradually reduce from 20 km to 10 km radius from the resource schools [Pers. Comm. MoEYS]. In order

to reduce the burden on the secondary resource schools, the Ministry also has made budget allocations to some network schools for constructing their own small-size laboratories [Pers. Comm. Bun Rany Hun Sen Chakriya Vong USS]. In the future, spatial analysis will be useful for analyzing a suitable location which is more conveniently accessible to network school networks. In the research, two different geographical areas were selected as case studies to examine the question of how to identify the appropriate location for secondary resource schools among lower and upper secondary schools in Banteay Meanchey (Figure 7) and in Phnom Penh (Figure 8).

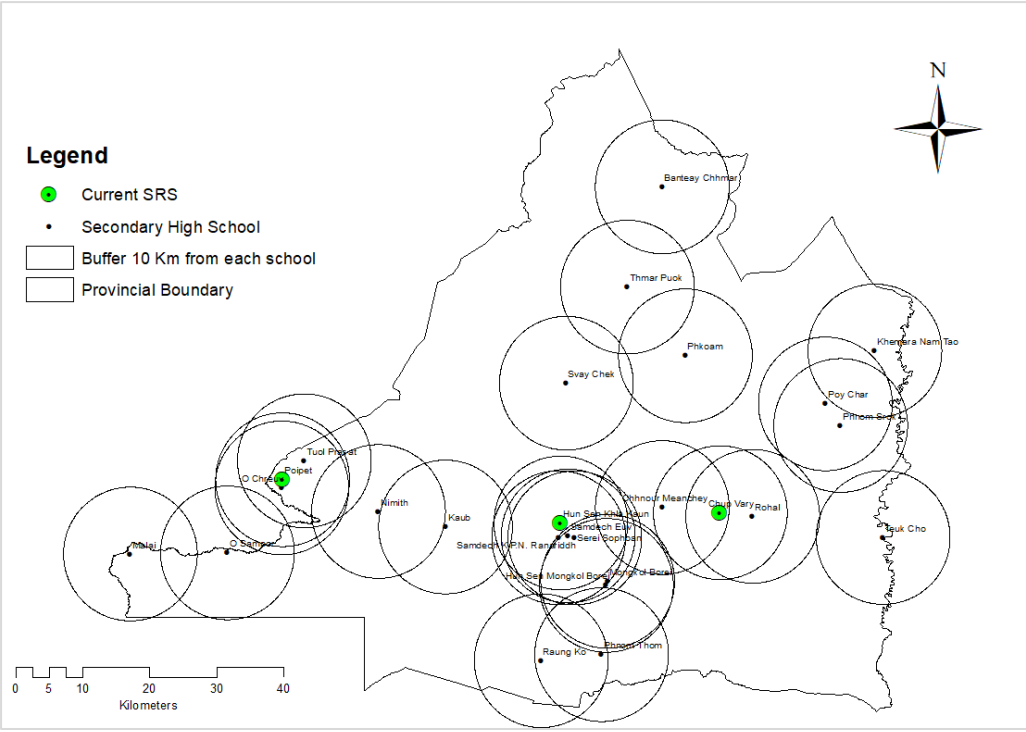

Figure 8: Appropriate location of secondary resource school in Banteay Meanchey

In Banteay Meanchey, three secondary resource schools were already constructed at Hun Sen Khlar Koun Upper Secondary School, Choub Veary Upper Secondary School and Poipet Krong Upper Secondary School. With spatial analysis, as illustrated in Figure 7, an appropriate location has been identified for the establishment of future secondary resource school in Banteay Meanchey. Similarly, spatial analysis can be applied in other provincial towns such as Kep or Kratie in order to find a more central Upper Secondary School to use as the host institution for the secondary resource schools. Figure 7 shows buffer zones, represented by a circle around the upper secondary schools which are represented by a dot on the map of Banteay Meanchey. Leaving aside the conditions of road access, the more circles around the

dot, the more central the location is. For example, Poipet Krong Upper Secondary School has three circles around it while Nimith Upper Secondary School has two circles and Malai has only one circle. So far, in Bantey Meanchey, the secondary resource schools have been central, or, within a 10 kilometer radius. Based on the analysis, Mongkol Borei would be the best option for the construction of resource school in the future since there were many upper secondary schools. In the future, secondary resource schools should probably be constructed at Samdach Ov or Serey Sophoan Upper Secondary Schools because they are more central and easier to be accessed by network schools.

In the case of Phnom Penh, the buffering radius should be about 5 Kilometers or less so that it would be very easy to commute (Figure 8). Based on that criteria, the analysis finds that the existing resources were not conveniently accessible by network schools. For example, the distance between Preah YouKunthor to Chbar Ampeouv Upper Secondary School ranges from 5.9 to 6.2 kilometers. It may take 30 minutes by bus, or less by motorbike, and more than one hour by walking. Locating a resource at Chbar Ampeouv Upper Secondary School helps to improve the quality of STEM education in a more suburban area of Phnom Penh, but also creates commuting issues for students among network schools. The establishment of the secondary resource school at Chbar Ampeouv Upper Secondary School was likely convenient for students at Hun Sen Chak Ang Re Upper Secondary School, Khdei Takoy Lower Secondary School, and Hun Sen Prek Pra Lower Secondary School. But, it has caused time consuming commutes for students from Beoung Trabek Upper Secondary School, Bun Rany Hun Sen Phsar Deoun Thkov, Preah Youkunthor Upper Secondary School, Toul Tum Poung Upper Secondary School, Chea Sim Beoung Keng Kang Upper Secondary School, and Sothearos Lower Secondary School. If the school provides transportation to students, it will consume a lot of time for students to commute. Moreover, it could be dangerous to let students go for individual transportation by motor bike or bicycle. The route to Chbar Ampeouv Upper Secondary School is one of the most traffic congested, especially during the peak hour. Students may be stuck there for hours if the traffic is heavy, and transportation definitely affects the schedule for network schools. Considering traffic congestion, safety concerns, and good access by the network schools, Santhor Muk Upper Secondary School is the most appropriate location for the future construction of a resource school. Moreover, Boeng Trabek Upper Secondary School location is optimal in terms of the distance from network schools. The location of the two schools are the most central in Phnom Penh for transportation from the network schools.

The establishment of a secondary resource school serves to create a primary education center for a geographic area. An SRS is located in the center of a province or a city for providing services to other surrounding network schools. The existing secondary resource schools are now only accessible to network schools near to the provincial or city center. Schools located further than 20 kilometers from the provincial center were unlikely to access the secondary resource schools [Pers. Comm. PDoEYD in Banteay Meanchey]. At Damrei Chorn Khlar Lower Secondary School, the school principal hesitated to send students to the secondary resource school at Hun Sen Balang Upper Secondary School because he felt there is a high risk when traveling such a far distance [Pers. Comm. Damrei Chorn Khlar LSS]. According to the Provincial Office of Education Youth and Sport, secondary resource schools have attracted applications for the student transfers because parents believe their children would receive a better education. For example, students at Phnom Sroc Upper Secondary School loved science courses but a laboratory was not available. As a result, many students transferred to another school with a laboratory. However, given the current realities of development and resource limitations, it would be very difficult to equip advanced laboratories like those found at the resource schools at all schools across the country. However, it is still important to provide for a small laboratory in every secondary school, as it is hard for students to have a solid understanding of physics and chemistry without a laboratory [Pers. Comm. PDoEYD in Banteay Meanchey].

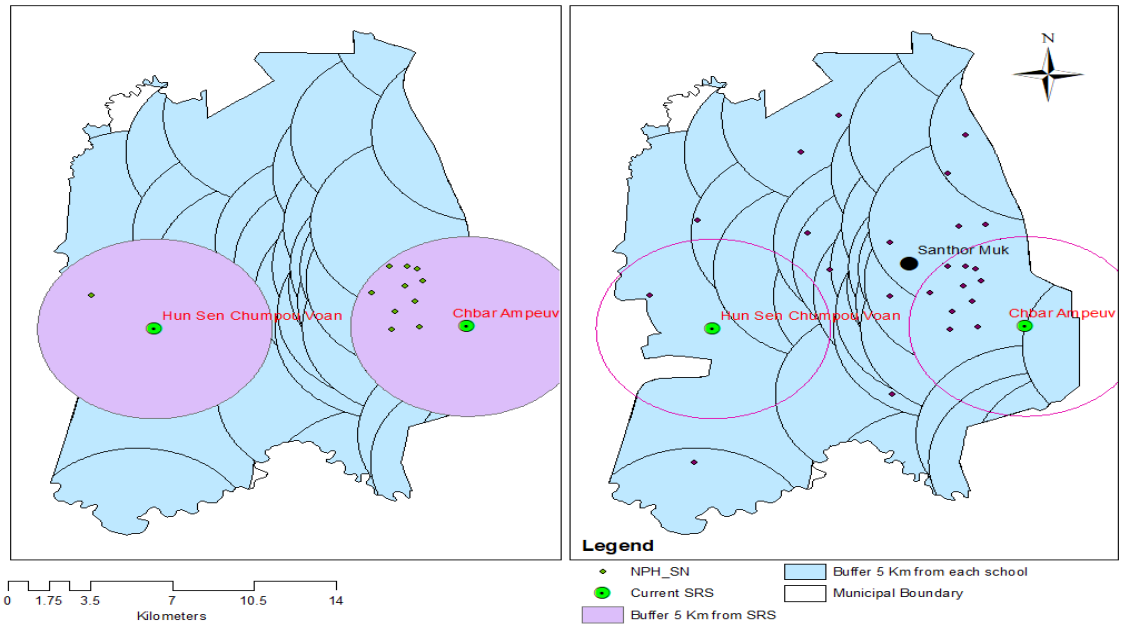

Figure 9: Appropriate location of resource school in Phnom Penh

During the field work, all the host schools were found to be satisfied with the establishment of secondary resource schools, but almost all of network schools used the secondary resource

school did so only because of the instruction of the Ministry and because they lacked alternative facilities. In promoting STEM education, many schools started to develop their small-scale laboratories to enable their students to do experiments and practice. For example, the Porng Tek Lower Secondary School renovated three rooms for preparing its own experimentation center for physics, chemistry and earth science. The Provincial Department of Education Youth and Sport in Banteay Meanchey also agreed that each school should have at least one small laboratory for more effective in teaching. Before the access to utilities such as electricity and water was one of the main obstacles, but it is not a problem anymore. [Pers. Comm. PDoEYD in Banteay Meanchey] By having a laboratory, students had opportunities to do more experimentation, however, the teachers did not have sufficient capacity for doing experiments. At Porng Tek Lower Secondary School, teachers only had the capacity to carry out simple experiments and repeat the same things. For example, many teachers of chemistry can only show students how to create oxygen, because they did not have any refresher training for new types of experiments. A lack of facilities, equipment and chemicals are also the issues. [Pers. Comm. Porng Tek LSS] At Hun Sen Krong Kep Lower Secondary School, there is no extra rooms for establishing an on-site laboratory, so teachers are buying portable chemicals/equipment to use in the classroom. [Pers. Comm. Hun Sen Krong Kep LSS]

3.4. Problems and constraints in managing secondary resource schools

An ultimate goal of establishing the secondary resource schools is to promote STEM education by improving facilities and equipment for practice and experimentation related to science courses. According to fieldwork interviews with all the key stakeholders including the MoEYS, the Provincial Office of Education, Youth, and Sport, school principals and officers in charge of secondary resource schools, five key problems are evident. These include obstacles in the areas of social norms, capacity, operation, and management which limit effectiveness of SRSs (Figure 9). Host schools stated that teachers and students from network schools were welcome to use the secondary resource schools [Pers. Comm. Hun Sen Khlar Koun USS]. Despite this, cultural and social norms have undermined the experience of teachers and students from network schools who come to use the secondary resource schools. The school principal at Hun Sen Chamkar Dong confirmed: "I have never heard any bad words from network school teachers. They were happy to use the secondary resource school here and thanked us for our help and cooperation. We have one staff standing by to assist them." [Pers. Comm. Hun Sen Chamkar Dong UPP] In contrast, various negative reactions were collected

in the feedback from networks schools regarding hospitality and support from the hosted school. The experience of teachers at Bun Rany Hun Sen Chakriya Vong Upper Secondary School resulted in dissatisfaction and the staff felt stigmatized when using the secondary resource school. "I feel hesitant to send my students to the secondary resource school when my students and teachers are not warmly welcomed. It is their house and they do not like our house. They are already busy with their students, so they have no time for students from network schools. It is supposed to have someone to stand by and assist us, but the officer in charge just locked the door and walked away for the whole time. When we asked something, they tended be unhappy to respond to our questions or request." [Pers. Comm. Bun Rany Hun Sen Chakriya Vong USS] By feeling that they were given differential treatment by the host school, network school visitors felt badly when using facilities equipped at the secondary resource schools. In Khmer culture and social norms, people feel something as ownership if it stays under one's authority or management even if it solely belongs to the public. Similarly, people feel guilty when taking advantage of the opportunity to use the secondary resource schools. The final evaluation of EEQP conducted in 2013 also concluded that network schools preferred to have their experiments at their own location. [Pers. Comm. MoEYS]

The research also discovered some limitations in the professional capacity among teachers at host schools and teachers at network schools. The school principal at Chbar Ampeouv Upper Secondary school expressed concern about the capacity of teachers who are using laboratories. "At every meeting or workshop, I always request for capacity-building of the people in charge of the laboratory. The main problem is that the instructions for the equipment are written in a foreign language and there is no translation into Khmer." [Pers. Comm. Chbar Ampeouv USS] In addition, there is not enough equipment for all the students to do practical activities, and so the experience is only available for some of them. When students go to do experiments at the secondary resource schools, some students just go for play because of insufficient equipment. Some other students are not able to comprehend what they are doing due to the lack of a clear explanation. In the past, teachers only drew pictures in order to explain to students about physics. At least, students can now see some demonstration from experiments. [Pers. Comm. Porng Tek LSS] Teachers at host schools are responsible for assisting teachers from network schools to do demonstrations or do experiments with students. Both of them had limited capacity in using the laboratory, especially any newer technology and science. The school principal at Hun Sen Chamkar Dong Upper Secondary School admitted that a lack of expertise to support the secondary resource school remained a key issue. Both teachers at host schools and network schools do not have sufficient skills to use and manage the laboratory effectively.

[Pers. Comm. Hun Sen Chamkar Dong UPP] Similarly, the school principal at Porng Tek Lower Secondary School commented that the building for the secondary resource school is large enough, but, the availability of equipment and chemicals is very limited. While teachers from school networks are not able to use the equipment well, teachers from host schools are not able to provide much assistance. [Pers. Comm. Porng Tek LSS]

> We have sufficient teachers; but, they have limited capacity to use the laboratory. At my school, we do not have human resource to manage laboratory equipment well. So we send teachers and students to the resource school because I expect they will both learned something from the people in charge. But the people in charge at the laboratory only help to arrange equipment and then hand over work to our teachers. I think the teachers who stand by at the secondary resource school also still have limited knowledge and capacity to use all the equipment well. They just have a bit more knowledge about experiments than our teachers. [Pers. Comm. Sandech Ov USS]

Figure 10: Problems and constraints in managing secondary resource schools

With regard to operations, the budget is not enough for covering the transportation cost of all the students to the secondary resource schools. At Tek Thlar Lower Secondary School, only 30 or 40 students were selected to go to the secondary resource school. In grade 7 alone, there were more than100 students, but only some of them were provided with the opportunity to do experiments. [Pers. Comm. Tek Thlar LSS] At Sandech Ov Upper Secondary School,

the available budget was able to send students in grades 11 and 12 to the secondary resource schools a few time per year in order to do experiments in the four subject areas of chemistry, biology, physics and earth science. The teachers also did some simple experiments at school because there were insufficient resources to cover the cost of transportation to the secondary resource schools on more occasions. [Pers. Comm. Sandech Ov USS] Teachers and students were complaining about insufficient support for transportation to resource schools. In addition, teachers were found it difficult to manage the transportation of students to the secondary resource school because of the lengthy distance from network schools [Pers. Comm. Porng Tek Lower LSS]. Furthermore, teachers were worried about the high risk to students when traveling individually to the secondary resource schools. The school principal at Damrei Chorn Khlar Upper Secondary School shared his experience: "There are not enough materials and equipment for students and teachers to use during their experiment at the secondary resource school. It was not easy to bring our students to other schools. When we arrive there, people in charge were not there. They wasted a lot of our time waiting. I think it is better to allocate funds to each school for doing their own experiments and practice. It is also such a waste of money to spend on transportation and the results from practice and experiments is small. If we do it at our school, we can make better quality experiments and practice." [Pers. Comm. Damrei Chorn Khlar LSS]

Management of the secondary resource school remained a great concern regarding scheduling experiments at SRSs of hosted school and school networks, the complicated procedure for requesting transportation expenditure, hygiene and campus cleanliness, and the quality of the building. According to the Department of Secondary Schools, resource schools have tight schedules so network schools were not able to allocate sufficient time to do experiments and practice. For example, each school network can only propose one hour per year for earth science [Pers. Comm. MoEYS]. In addition, a laboratory could only accommodate between 20 and 30 students. If there were more students, they were sent to the library. In some cases, students were not interested much in the library because their school also had library. [Pers. Comm. Chbar Ampeouv USS] There were many inconvenient experiences faced by network schools when requesting to use the secondary resource school. For example, at Chbar Ampeouv Upper Secondary School, resource schools were always fully booked and it was quite hard to get a respond to the further request for adding the network school to the schedule. This resource school needed more facilities to provide enough services for network schools. [Pers. Comm. Chbar Ampeouv USS] Teachers from network schools found it difficult to arrange the financial statement of expenditures after sending students to

the secondary resource school. [Pers. Comm. Hun Sen Krong Kep LSS]. Moreover, the cleanliness management of the secondary resource school required improvement, such as toilet hygiene. The internal regulation of resource schools was also needs to be strictly enforced. The request form for using the secondary resource schools should be fixed and not changing all the time, as it is wasting the time for learning. [Pers. Comm. Hun Sen Krong Kep LSS] At Hun Sen Balang Upper Secondary School, the building was suddenly broken into after the construction. Some rooms were also broken into. The school contacted the Provincial Department of Land Management Urban Planning and Construction for inspection of this mater. The building is now fine for use. [Pers. Comm. Hun Sen Balang USS]

4. Discussion and policy implication

4.1. Promoting stem education through establishing secondary resource schools

In order to engage more students in learning STEM subjects, they need access to STEM experiment and practice more often and more effectively. Schools, therefore, need to provide facilities, and equipment for students to learn STEM and teachers need to be prepared to teach STEM. Access to equipment and professional development will ensure that teachers can provide motivating and engaging lessons for students learning STEM subjects. According to the interviews with the Department of Secondary School of MoEYS, the establishment of a laboratory at each school is a long-term process and it requires a very large government budget. At the moment, the MoEYS does not have sufficient budget to establish a laboratory at each school, so the secondary resource schools function as an alternative. Evidence from this research confirms that secondary resource schools do contribute to promoting STEM education in Cambodia. At Hun Sen Chamkar Dong Upper Secondary School, the secondary resource school has been used to host contests and a science exhibition which promoted STEM education. Also, the secondary resource schools are providing preparation and training of the outstanding students for the national competition. In 2019, students from Hun Sen Chamkar Dong Upper Secondary School won third place in the science competition. According to the Department of Secondary Schools of MoEYS, there were 176 students including 71 females at the 50 resource schools who got an 'A' on the national examination for upper secondary school; it accounts 37% of the nation-wide 'A' scores. This achievement clearly demonstrates the increased interest in STEM education by students at the secondary school.

In Cambodia, public schools have restricted access to laboratory for experiment and practice for students and teachers because of (1) dependence on the government budget, and (2) lack of

their own income generation. Without laboratory facilities and equipment, there are few opportunities for students and teachers to engage in science, this lack of access to appropriate material resources restricts scientist's creativity in experimental designs and contributes to a reproducibility crisis as learners struggle to replicate the work of peers. Under USESDP II, some school networks have been granted with a budget for establishing their own laboratory. By doing so, it would not only reduce the burden of the secondary resource schools, but also increase the opportunity for students at the former network schools network to be able to experiment and practice more. However the secondary resource schools remain useful for network schools because facilities and equipment are much more advanced and sufficient. Network schools may consider bringing students to use the secondary resource schools when they require more advanced facilities and equipment. At the same time, other network schools may consider to establish their own simple laboratories for experiment and practice. The schools may start with materials or equipment which can be produced by teachers at the school. As each network school gains its own simple laboratory, the number of visits at the secondary resource schools will gradually be reduced. As a result, the available budget provided for covering the transportation cost to the secondary resource schools can be used for car rental, to improve safety of students and teachers.

Alternatively, the operation of a mobile laboratory in each province across the country could probably help to spread wider access for network schools or even secondary schools in remote areas. These laboratories on wheels would be used for science education to support STEM education at secondary schools. The mobile laboratories would travel to schools and provides the schools with educational resources which they otherwise lack. The mobile laboratories would be staffed by experts which require for students to practice for example physics, chemistry, biology and earth science. The mobile laboratory van is equipped with full-size instruments for an extensive scope of experiment and practice for students at secondary schools. The management of mobile laboratories would be similar to the secondary resource schools, but they would be under the direction of the Provincial Department of Education Youth and Sport. The secondary schools are able to request the mobile laboratory van for one week to stand by at their schools, enabling teachers and experts to work together to support students to do experiment and practice. The choice of operating mobile laboratory van would probably be the most cost-effective in promoting STEM education because accessibility would be more homogenous across the country. In addition, the cost of establishment and operation would be more affordable.

4.2. Determining the appropriate location of the secondary resource schools in Cambodia

The findings of this research clearly confirm that locations of the existing secondary resource schools in Kampong Thom, Kratie, Kep, Banteay Meanchey and Phnom Penh are not spatially optimized. The policy by the MoEYS to locate the secondary resource schools establishes the following criteria: (1) the school is located in the center of the province municipality or district (khan); (2) there are both good school management and good community cooperation; (3) the school size allows for future building expansion; (4) the school is regarded as safe and secure for storage of expensive equipment; and, (5) there are electricity and water supplies provided for the computer and laboratory location. The criteria that electricity and water utilities are available, is no longer relevant as those services now exist everywhere across the country. In addition, the criteria of location should probably weigh heavier among the five standards. At this time, it is not clear how much weight is given to the different criteria. According to the fieldwork, criteria such as the population of students per school, the availability of experts in the fields of science, and good collaboration between host schools and network schools should also be taken into account.

Furthermore, it is important to apply a feasibility study and spatial analysis when selecting the location of secondary resource schools. A feasibility study helps to collect information about the perception of students and teachers at both the secondary resource schools and network schools. Based on the results, current issues and problems related to social norms, capacities, operations, and management, can probably mitigated. Moreover, Geographical Information Systems (GIS) can be used to identify the most suitable new school location. In addition, the feasibility study and GIS application are useful for planners and project designers to select the locations which most easily accessible by all network schools. In addition, the feasibility study helps to enhance operations, capacity-building and perceptions of host schools and network schools for better management of the secondary resource schools. In general, host schools experience more benefits from the use the secondary resource schools than network schools because of far distance, insufficient transportation funds and experimental equipment, and ineffective schedule management for booking the use of the laboratories.

To identify appropriate locations for secondary resource schools, Phnom Penh and Banteay Meanchey were selected as case studies. The best location for the establishment of secondary resource schools are in Mongkol Borei for Banteay Meanchey as well as Boeng Trabek Upper Secondary School and Santhor Muk Upper Secondary School for Phnom Penh. The selection of these locations for secondary resource schools are considered best because

they would help to increase access by network schools with more affordable transportation cost, less traffic, and more safe travel by students and teachers. In addition, convenient access helps to increase the frequency of visits to the secondary resource schools by network schools. In the future, secondary resource schools should be established in a central location, where there are many lower and upper secondary schools. In order to carry out a sound spatial analysis for determining the appropriate location of secondary resource schools, GIS applications and feasibility studies should be utilized to arrive at decide on the optimal locations.

4.3. Policy implication for the establishment of secondary resource school in Cambodia

After participating in experiments at secondary resource schools, students change in a positive manner because they are able to learn more from real demonstrations. There is no doubt that it is impossible to promote STEM education without laboratories and it is impossible to make laboratories possible at all the lower and upper secondary schools across the country in the near future. As a result, the construction of secondary resource schools is still the best choice. However, there is a need to improve the cooperation between host schools and network schools. In addition, the effectiveness of operations management as well as capacity building of teachers at both host schools and network schools needs to be improved. In order to increase the frequency of visits and the purchase of equipment of the school networks, the budget amount of USD 500 should be increased. In relation to the management of the laboratories, all equipment in each laboratory should be labeled in the Khmer language so that all the teachers and students can understand it. In addition, schedule preparation should be improved in order to increase ease of use of the secondary resource schools. Capacity building should be carried out after a needs assessment is conducted, so that the course would be able to respond to the real needs of the teachers and students.

Alternatively, small-size laboratories constructed at network schools also resolve some of the issue of reducing the burden on secondary resource schools. However, it requires time to build sufficient laboratories across the country, and the current construction efforts gradually helps to reduce the problem. The network schools should also carry out simple experiment and practice at their schools, and, the schools should only come to the secondary resource schools when they require advanced equipment. In some cases, teachers can only perform simple experiments in their own school rooms to help students to associate theories with practice. The operation of mobile laboratory not only extends the accessibility of network schools, but it also

helps to increase the access for schools in remote areas. In comparison to the construction of new secondary resource schools, procuring the usage of a mobile laboratory would be less expensive. In particular, its mobility allows it access to remote locations, and can increase the frequency of access by students across schools.

5. Conclusion

Based on the findings of surveys conducted in Kampong Thom, Kratie, Kep, Banteay Meanchey and Phnom Penh, , it can be concluded that the establishment of secondary resource schools in the 25 provinces and cities has contributed to the promotion of STEM education in Cambodia. The secondary resource schools are providing students with opportunities to do experiments and practice in the fields of physics, chemistry, biology and earth science. However, the gap between host schools and network schools was large because host schools already enjoyed all the benefits of the secondary resource schools. Network schools were confronted with obstacles that resulted from of insufficient transportation funds, limited capacity of teachers at the host schools and network schools, and weak operation and management at the host schools. Since 2004, the ADB has funded the establishment of secondary resource schools through three different projects, they include the ESDP II, the EEQP, and the USESDP. Today, 50 secondary resource schools have been instituted throughout Cambodia.

On average, there are two secondary resource schools established in each province. The research confirms that the number of secondary resource schools was passively and strongly correlated to the number of students, to the number of secondary schools, and to the number of network schools. In order to operate the secondary resource schools and network schools, the ADB and the MoEYS are also providing them with an annual budget for operations of the resource school, transportation, the purchase of materials purchase, and a scholarship scheme for poor students. The average distance between secondary resource school and network schools was 4.2 kilometers, with distances ranging from 2.0 to 9.4 kilometers. Comparatively, Kratie had the furthest average distance and Banteay Meanchey had the nearest. Due to limits on the government budget, it will be quite challenging for Cambodia the construction of equipped laboratory facilities for experiments at all secondary schools in Cambodia in the next 10 years.

As an example, Banteay Meanchey and in Phnom Penh were selected as case studies to explore the question of how to identify the appropriate location for secondary resource schools.

In the future, the establishment of secondary resource schools can be done at Samdach Ov or Serey Sophoan Upper Secondary Schools. In Phnom Penh, Santhor Muk Upper Secondary School or Boeng Trabek Upper Secondary School are likely to optimize the distance between network schools. In managing the secondary resource schools, four key problems were found; they included social norm, capacity, operation, and management. While, network schools felt less hospitality, host schools faced challenges stemming from operation on small annual budget, management of schedules, and service to support network schools. In particular, host schools and network schools did not have sufficient capacity in using the laboratory effectively and efficiently.

References

Achieve, Inc. (2013) Next Generation Science Standards Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS. Washington, DC: Author.

ADB (2012) Cambodia: Second Education Sector Development Program. Phnom Penh: Asian Development Bank.

Ainley, J., Kos, J. & Nicholas, M. (2008). Participation in science, mathematics and technology in Australian education. ACER research monograph No. 63. Camberwell, Victoria: ACER.

Angus, R. Ross, & Keith, M. Lewin (1992) Science kits in developing countries: an appraisal of potential. International Journal of Educational Development. Incomplete. Paris, UNESCO.

Anonymous. (2015, July 3) Building an interest in STEM Education. Retrieved May 12, 2016, from The Phnom Penh Post: http://www.phnompenhpost.com.

Armbrecht, D. (2016, February) Which degree will get you hired? Retrieved May 12, 2016, from World Economic Forum: https://www.weforum.org.

ASEAN Secretariat (2007) Cebu Declaration on the Acceleration of the Establishment of an ASEAN Community by 2015. Retrieved on March 18, 2015, from http://www.asean.org/news.

Blanquat, S., & Associates (2016) STEM Careers of the Future. Phnom Penh: British Embassy Phnom Penh

CDC (2015) Cambodia Industrial Development Policy 2015 – 2025. Phnom Penh: Council for the Development of Cambodia.

English, L. (2017) STEM education K-12: Perspectives on integration. International Journal of STEM Education, 3(1), 3.

Goldstone, R. L., & Sakamoto, Y. (2003) The transfer of abstract principles governing complex adaptive systems. Cognitive Psychology, 46, 414-466.

Kaing, S. (2018) How Can STEM Education Help Stimulate Economic Growth in Cambodia. Brussel: Vrije Universiteit Brussel.

Kao, S. (2013) Factors Affecting Students' Choice of Science and Engineering Majors in Higher Education of Cambodia (Master Thesis). Hiroshima: Hiroshima University.

Kigali Institute of Education Teacher (KIE, November 2011). Teacher Training Colleges, Appendices for Science Teaching Methodology Curriculum, Option: Science and Mathematics. Kigali Rwanda.

Luft, J. A., Firestone, J. B., Wong, S. S., Ortega, I., Adams, K., & Bang, E. J. (2011) Beginning secondary science teacher induction: A two-year mixed methods study. Journal of Research in Science Teaching, 49(10), 1199-1224.

Machuve, J., & Mkenda, E. (2019) Promoting STEM Education Through Sustainable Manufacturing: Case Study of Photovoltaic Toys. Procedia Manufacturing, 33, 740-745.

MoEYS (2014) Education Strategic Plan 2014-2018. Phnom Penh: Ministry of Education Youth and Sport.

MoEYS (2015) Education strategic plan 2015-2018. Phnom Penh, Cambodia: Ministry of Education, Youth, and Sport

MoEYS (2015) Enhancing Education Quality Project (EEQP). Project completion report. Phnom Penh: Ministry of Education Youth and Sport.

MoEYS (2016) Policy on Science, Technology, Engineering and Mathematics (STEM) Education. Phnom Penh: Ministry of Education Youth and Sport.

MOEYS (2018) STEM Education Achievement. Phnom Penh: Ministry of Education, Youth and Sport.

National Research Council (NRC) (1996) National science education standards. Washington, DC: National Academy Press.

National Science Board (2015) Revisiting the STEM workforce: a companion to science and engineering indicators 2014 (pp. 46). Arlington: National Science Foundation.

Ogunmade, T. O. (2005) The status and quality of secondary science teaching and learning in Lagos State, Nigeria.

Pimthong, P., & Williams, J. (2018) Preservice teachers' understanding of STEM education. Kasetsart Journal of Social Sciences.

Recayi, P., Jill, H., Faruk, Y. (2012) Promoting STEM to Young Students by Renewable Energy Applications. Journal of STEM Education, 13, 62-73.

Sandifer, C., & Haines, S. (2009) Elementary teacher perceptions of hands-on science teaching in an urban school system: The greater educational context and associated outcomes. Research in higher education Journal, 2(3), 117.

Suleiman, M.M. (2013) Exploring Science Teachers' Experiences of Teaching Science with Limited Laboratory Resources: A Case Study of Community Secondary School in Lindi, Tanzania (Master's Dissertation).

Tytler, R. (2007) Re-imagining science education: Engaging students in science for Australia's future. Australian Education Review. Camberwell, Victoria: ACER.

USAID (2010) Review of Cambodia's science and technology policy and science, technology education and mathematics (STEM) education policy and practice (Report No. 2). Jakarta: United States Agency for International Development.

World Bank (2016) Enhancing Export Competitiveness. The Key to Cambodia's Future Economic Success. Phnom Penh: World Bank.

Appendix: List of interviewees

Code	Organizations	Date
MoEYS	Ministry of Education Youth and Sport	November 2019
Porng Tek LSS	Porng Tek Lower Secondary School	October 2019
Hun Sen Krong Kep LSS	Hun Sen Krong Kep Lower Secondary School	October 2019
Bun Rany Hun Sen Chakriya Vong USS	Bun Rany Hun Sen Chakriya Vong Upper Secondary School	October 2019
Hun Sen Chamkar Dong USS	Hun Sen Chamkar Dong Upper Secondary School	October 2019
PDoEYD in Banteay Meanchey	Provincial Department of Education Youth and Sport in Banteay Meanchey	November 2019
Hun Sen Khlar Koun USS	Hun Sen Khlar Koun Upper Secondary School	November 2019
Tek Thlar LSS	Tek Thlar Lower Secondary School	November 2019
Sandech Ov USS	Sandech Ov Upper Secondary School	December 2019
Serey Sorphorn USS	Serey Sorphorn Upper Secondary School	December 2019
Chbar Ampeouv USS	Chbar Ampeouv Upper Secondary School	December 2019
Hun Sen Prek Pra LSS	Hun Sen Prek Pra Lower Secondary School	December 2019
Bun Rany Hun Sen Phsardeounthkov USS	Bun Rany Hun Sen Phsardeounthkov Upper Secondary School	December 2019
PDoEYD in Phnom Penh	Provincial Department of Education Youth and Sport in Phnom Penh	December 2019
On Chanh LSS	On Chanh Lower Secondary School	November 2019
Kratie Krong USS	Kratie Krong Upper Secondary School	November 2019
Damrei Chorn Khlar LSS	Damrei Chorn Khlar Lower Secondary School	November 2019
Hun Sen Balang USS	Hun Sen Balang Upper Secondary School	November 2019
PDoEYD in Kampong Thom	Provincial Department of Education Youth and Sport in Kampong Thom	November 2019
Stung Sen USS	Stung Sen Upper Secondary School	November 2019
Panha Chi LSS	Panha Chi Lower Secondary School	November 2019