# STEM AND EDUCATION TECHNOLOGY IN BANGLADESH, CAMBODIA, THE KYRGYZ REPUBLIC, AND UZBEKISTAN

## A SYNTHESIS REPORT

JUNE 2022

ASIAN DEVELOPMENT BANK

ADB

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Note:
In this report, "$" refers to US dollars.

On the cover: STEM and education technology are becoming increasingly important in strengthening the professional development of educators and significantly improving student learning outcomes (photos by ADB).

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# ACKNOWLEDGMENTS

# ABBREVIATIONS

ADB — Asian Development Bank

COVID-19 — coronavirus disease

DMC — developing member country

EdTech — education technology

EMIS — education management information system

ICT — information and communication technology

NGO — nongovernment organization

SIS — school information system

STEM — science, technology, engineering, and mathematics

# EXECUTIVE SUMMARY

This publication focuses on the state of science, technology, engineering, and mathematics (STEM) education and education technology (EdTech) in four developing member countries (DMCs) of the Asian Development Bank (ADB): Bangladesh, Cambodia, the Kyrgyz Republic, and Uzbekistan. It presents studies conducted from May 2020 to May 2021, along with situation analysis reports on EdTech and describes the state of information and communication technology (ICT) in the general education subsectors (primary and secondary) of the four DMCs. It discusses findings from the country studies, identifies gaps and potential intervention areas, and provides policy and intervention recommendations.

## STEM Education

Findings from a survey of STEM teachers yielded a wealth of data on 11 subscales:

(i)     syllabus in teaching
(ii)    assessment
(iii)   textbooks
(iv)    preservice teacher training program
(v)     inclusion of ICT
(vi)    students' interest
(vii)   professional development programs
(viii)  pedagogy
(ix)    project work
(x)     innovations in education and laboratory
(xi)    design and technology workshops

Based on the survey samples, perception ratings by the teachers on the state of STEM education in their schools and countries are not high. In addition, further findings were gathered from the qualitative responses of teachers to four open-ended questions:

(i)     three aspects that teachers are already good at
(ii)    three challenges they face in teaching STEM in school
(iii)   two improvements that schools can make to improve teaching and learning in their STEM subjects
(iv)    one way in which the country can become strong in STEM education

A survey of school leaders also yielded a wealth of data on five subscales:

(i)     school leadership
(ii)    school improvement
(iii)   relationship with national education authorities
(iv)    relationships with other stakeholders
(v)     professional development of teachers

Perception ratings by school leaders on the effectiveness of education in their schools and countries are not high. The qualitative responses of school leaders to four open-ended questions also highlighted further findings. The questions focused on the following:

(i)     three things that are working well in schools
(ii)    three challenges faced by schools
(iii)   two improvements schools can make to improve teaching and learning
(iv)    one way in which countries can become strong in education

Examination of internet resources as well as confirmatory discussions with stakeholders indicate the absence of science centers set up in the classical manner. Also absent are nongovernment organization (NGO)-based scientific academies and scientific societies in the four DMCs. This shows a big gap as well as an opportunity to identify and develop complementary resources that could effectively contribute to institutionalizing STEM education through a network of critical stakeholders in the DMCs, as done by other successful countries.

A comparison of STEM education in the four DMCs with Finland and Singapore shows that there are several areas for improvement, mainly in relation to preservice teacher education, teacher professional development, STEM education practices, the presence of external providers of STEM education, the establishment of a high bandwidth access to internet in schools, and the promotion of research activity levels of teacher education institutes.

In light of the findings, suggestions to improve the state of STEM education in the four DMC include the following:

(i)     Improve students' interest levels in science and mathematics.
(ii)    Ensure that STEM teachers attend regular in-service courses as part of their professional development and enhance latest developments on STEM education.
(iii)   Improve preservice and in-service teacher education in STEM subjects to enhance pedagogical practices that contribute to improvement in student learning outcomes.
(iv)    Further develop the research expertise of academic staff at teacher education institutes.
(v)     Establish science centers to popularize STEM.
(vi)    Form NGO-based scientific societies to further boost activity levels of STEM education.
(vii)   Promote integrated STEM education initiatives through low-cost initiatives.
(viii)  Significantly increase the internet bandwidth in schools.

Given ADB's recognition of STEM education in improving pedagogical practices and learning outcomes, particularly of girls and disadvantaged and marginalized students, some suggestions for further work are also provided. Most of these relate to organizing workshops in relation to the proposed suggestions

for improving the state of STEM education in the four DMCs, organizing various courses for pre-service teacher educators and other trainers of STEM subjects, forming local committees with ADB representatives to oversee the implementation of some recommendations, and establishing and strengthening knowledge partnerships with centers of excellence with proven expertise in STEM education, and providing some seed funding to jump-start the suggested initiatives.

The two surveys on STEM teachers' views about STEM and school leaders' views of the education system have good psychometric validity and reliability. As a next step, these can be used to map the state of STEM education in other DMCs, with some fine-tuning in phrasing to suit local contexts.

# EdTech

With the pervasive adoption and usage of ICT in every sphere of life, mastery of those technologies becomes a fundamental requirement for work in the 21st century. Technologies in education systems or so-called "education technologies" (EdTechs) are providing new opportunities for students, teachers, education officers, and families to enhance learning and equity-at-scale by creating engaging, inclusive, and individualized learning experiences.

ADB commissioned the studies on Bangladesh, Cambodia, the Kyrgyz Republic, and Uzbekistan to gain insights on the current state of EdTech in the general education sector and how it is adapted and used in facilitating the learning outcomes and 21st century employability skills. The studies aimed to fill gaps in knowledge (including the early developments associated with the coronavirus disease [COVID-19] pandemic) as well as map the existing body of knowledge to inform ADB's five-pillar assessment framework. The studies are also geared toward developing methodologies for collecting information on the digital learning readiness of DMCs.

The five domains and dimensions of the research framework are the following:

(i)    **Infrastructure.** The situation related to the state of the ICT infrastructure in the country, including its quality and accessibility to students. Four key components are evaluated: internet connectivity, devices, power networks, and broadcasting.

(ii)   **Government.** The situation related to enabling legislation and government policies and actions (laws, policies, funding, plans, strategy, and road maps) to support the role of EdTech in enhancing education outcomes. It specifically looks at the following four areas: policies and funding, curriculum, education performance measurement, and preservice training.

(iii)  **Schools and teachers.** The situation related to the capacity of schoolteachers and school administrators. The key areas studied are teacher capacity in EdTech; in-service training; equipment and software in schools; and governance (school policies, budget, monitoring for quality learning outcomes).

(iv)   **Parents and students.** The quality of home or community environment in terms of facilitating or enabling the achievement of student learning outcomes. These include digital literacy of students, connectivity and devices at home, online access to curriculum content, digital skills, and community support.

(v)    **Providers.** The insight is about the quality of EdTech systems and providers and education sector partnerships. It includes a review of learning management, e-learning systems, online content, integrators, developers, and sponsors.

The most important finding was the need for shifting to a technology-inclusive ecosystem approach that would enable EdTech to transform education, away from the piecemeal and siloed approach seen in many DMCs. EdTech is not about simply replacing the current face-to-face mode of teaching and learning. It is about digitizing teaching, learning, and administrative processes while promoting adaptive or personalized learning through a collaborative process that combines the power of technology (data and evidence), with creative pedagogical practices that support learning and equity at scale.

It is paramount for educationists to cross boundaries and interact with a variety of stakeholders because success in EdTech delivery depends on understanding and implementing beyond the normal capacity of one government agency. EdTech requires new ways of envisioning education systems and enabling interaction between students and teachers, and curricula must be adjusted as content, delivery style, and organization also transform.

# SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS

## Background

Science, technology, engineering, and mathematics (STEM) education is increasingly being emphasized today. Modern economies are driven by science and technology, in contrast to the traditional land–labor–capital model of development. Thus, it is important for developing countries to be well-versed in STEM (Tan and Subramaniam 1998, 2014). The importance of STEM education has been articulated by both policy makers and researchers. A number of international journals have also come up with special issues on STEM education; for example, Camilli and Hira (2019) and Tan and Subramaniam (2021).

While STEM is commonly used by policy makers and teachers, technology and engineering are not mainstreamed school subjects in most countries. When referring to STEM education, either in the school education system or in preservice teacher education, we are generally focusing only on science and mathematics. Hence, these will be the main focus of this paper, i.e., primary science, lower secondary science, physics, chemistry, biology, and mathematics as well as earth science, where applicable.

There has been growing interest also in "makerspace" and "tinkering" activities, design thinking, and coding to promote inquiry-based and project-based learning. These also involve STEM beyond the confines of the school curricula. The extent that these are being promoted in the four developing member countries (DMCs) of the Asian Development Bank (ADB)—Bangladesh, Cambodia, the Kyrgyz Republic, and Uzbekistan—will be explored. For this study, we are not looking into science, technology, engineering, arts, and mathematics (STEAM), which is similar to STEM, but with the incorporation of arts as a discipline.

## Introduction

This study, funded by ADB, explores the state of STEM education in four of ADB's DMCs: Bangladesh, Cambodia, the Kyrgyz Republic, and Uzbekistan. This report on the state of STEM education in the four DMCs is useful for the following reasons:

(i)  It provides baseline information on where each DMC stands in STEM education.
(ii)  It allows benchmarking with the best practices of other countries.
(iii)  Policy makers and other stakeholders can see the extent of interventions needed in the education system to ramp up efforts in STEM education.

A common perception in many countries is that the education system is solely responsible for promoting STEM education in a country. This is an issue with a number of developing countries. Other contributors in a country that advocate STEM education should also be harnessed.

## Project Description

Country-level studies of STEM readiness in the four DMCs were explored in close collaboration with ADB's operations departments and the national consultant in each of the DMCs. The study analyzed the key institutions involved in STEM education and the country-level plans to support STEM education. The study also developed a road map for institutional strengthening and capacity development of key institutions involved in curriculum and assessment, preservice teacher education, teacher professional development, and school leadership development.

In consultation with ADB's Education Sector Group Secretariat and regional departments, the focus were on the following activities:

(i)   analyzing the current situation of STEM education and policies related to it in Uzbekistan;
(ii)  identifying international good practices and lessons on STEM education, which are applicable for the four DMCs in context; and
(iii) undertaking consultations with key stakeholders, such as those in selected schools as well as provisional and district education offices.

## General Findings

According to the stakeholders, the current problems faced by the general secondary education system in implementing STEM education are:

(i)   shortage of teachers in mathematics, physics, chemistry, biology, and computer science;
(ii)  absence of training programs offered for the preparation of integrated STEM education teachers in preservice and in-service education;
(iii) lack of modern laboratories and technical equipment required for education in STEM subjects;
(iv)  lack of educational and methodological frameworks (textbooks, workbooks, and teacher guides) for integrated STEM education; and
(v)   insufficient funding; the bulk of state budget expenditure on public education is on wages, while limited funds are allocated for renewal of school equipment and materials as well as renovation of school buildings.

Based on stakeholder interviews, the following were also noted:

(i)   There is strong government support for improving STEM education.
(ii)  Education authorities have started some initiatives for improving the state of STEM education in the countries.
(iii) Curriculum developers lack understanding about integrated STEM education or how to develop such programs.
(iv)  Measurement criteria for evaluation of teacher performance and student performance need further upgrading.

In many developed countries, science centers have been established to popularize science and technology (including mathematics) to students and the public (Tan and Subramaniam 1998, 2003).

Based on research for the four DMCs, there were no science centers that were set up on the classical model in these DMCs, that is, science centers with a mission to popularize science and technology to students and the public. This would commonly entail having interactive exhibits in exhibition galleries, science enrichment programs for school students, and promotional activities to further reach out to students and the public. This was further confirmed during discussions with key stakeholders. The absence of science centers in the four DMCs limits the scope for such institutions to open another tributary for the cause of promoting STEM education in the country.

**State of scientific academies and scientific societies.** In the developed world, scientific academies and scientific societies play an important role in promoting the various scientific disciplines, engaging in scholarly endeavors such as journals publishing, and establishing outreach activities for schools and the public (Tan and Subramaniam 1999, 2009; and Tan, Wee, and Subramaniam 2017). The early scientific academies and scientific societies were run by volunteers drawn from universities and the professions. In the case of Singapore, they operate without premises and are run as nongovernment organizations (NGOs).

In the four DMCs studied, there were no scientific academies and scientific societies that are modeled along NGO lines such as the Singapore National Academy of Science and its constituent discipline-based scientific societies. This was further confirmed during discussions with key stakeholders. However, there are scientific academies in all the four DMCs that are established along traditional lines; for example, those that focus on research funding, or election of fellows. The absence of NGO-based scientific societies in the four DMCs limits the scope for such grassroots-based organizations to open another tributary for the cause of STEM education in the country.

**Teacher education institutes.** Preservice teacher education is done mainly by teacher education institutes. There are teacher education institutes in each of the four DMCs. The presence of teacher education institutes in a country ensures support for the cause of teacher education as well as teachers' professional development. Teacher education institutes and related organizations thus play a useful role for the cause of STEM education in the respective subjects in the country.

In developed countries, teacher education institutes are also active in research. Major scholarly databases indicate an absence of research papers published from the four DMCs in the areas of sciences and mathematics education, including STEM education. Low research activity levels indicate that teacher education institutes may find it difficult to play a stronger role in supporting the wider cause of teacher education in curriculum studies courses in the sciences and mathematics that are in sync with mainstream practices and informed by research. Research activity levels help boost capacity building of academic staff in these institutes and need to be embraced by staff.

Generally, departments in universities offering undergraduate education in the sciences do not conduct educational research as this is the staple of teacher education institutes.

**Teacher professional development.** In each of the four DMCs, a few organizations are involved in offering professional development programs for teachers. However, there is not much information about the range of such programs, the quality of the offerings, and the number of teachers they reach out to.

## *Findings from STEM Teachers' Survey*

Key points in the survey are the need to enthuse students about STEM subjects, improve preservice teacher preparation, and provide teachers with more professional development programs. A full analysis of the survey is presented in the respective country reports.

**Perception rating of the effectiveness of STEM education.** The survey also sought respondents' views on the effectiveness of STEM education from a number of perspectives. In relation to the state of STEM education in their school, the mean rating slightly exceeds *average* but is below *high* and suggests that there is quite some room to improve the effectiveness of STEM education in their schools. A similar rating was given for the state of STEM education in their country and their overall attitude toward STEM education. These are for all the four DMCs.

The survey also included four open-ended questions for which STEM subject teachers were requested to elaborate on their responses. The open-ended questions are:

(i)    aspects that they are already good at,
(ii)   challenges that they faced in teaching of their STEM subjects in school,
(iii)  improvements that the school can make to teaching and learning in their STEM subjects, and
(iv)   ways in which the country can become strong in STEM education.

Overall, a wealth of findings has been uncovered from the open-ended questions. Respondents have been very frank in their responses. What comes out strongly are that (i) internet connectivity needs improvement/development, (ii) information and communication technology (ICT) needs to be more integrated into the classroom, (iii) teachers need to be upskilled with the requisite competencies for the challenges of the new educational landscape, (iv) laboratories should be well-resourced, and (v) textbook quality needs improvement/development.

## *Findings from the School Leaders' Survey*

The quality of education in STEM subjects in schools depends significantly also on how the leadership is poised for the challenges ahead in the context of nation building. Effective leaders can drive the STEM education agenda further.

In relation to the effectiveness of education in the school leaders' schools, the mean rating exceeds *average* but is below *high*, thus suggesting that there is quite some room to improve effectiveness of education in schools in the four DMCs. A similar rating was given for the effectiveness of education in their country and their overall attitude toward education for all the four DMCs.

Open-ended questions were also asked of the school leaders. Useful findings were obtained for:

(i)    aspects that are working well in the school,
(ii)   challenges faced in the school,
(iii)  improvements that the school can make to improve teaching and learning, and
(iv)   ways in which the country can become strong in education.

The message is that educational polices, teacher recruitment, and supporting infrastructure need improvement, and teachers need more support for professional development.

## Comparison with Other Countries

A comparison of the state of STEM education in the four DMCs with Finland and Singapore is in Table 1.

**Table 1: Comparison of STEM Education in the Four Developing Member Countries with Finland and Singapore**

| Item | Finland | Singapore | Bangladesh | Cambodia | Kyrgyz Republic | Uzbekistan |
|------|---------|-----------|------------|----------|-----------------|------------|
| Standard of preservice teacher education in STEM subjects | High | High | Developing | Developing | Developing | Developing |
| Teacher professional development | High | High | Developing | Developing | Developing | Developing |
| STEM education practices | High | High | Developing | Developing | Developing | Developing |
| Integrated STEM as a subject in mainstream schools | Yes, in primary schools | No | No | No | No | No |
| Research activity levels of teacher education institutes | High | High | Developing | Developing | Developing | Developing |
| Presence of science centers | Yes | Yes | No | No | No | No |
| Long history of scientific academies and scientific societies for the cause of national science development | Yes | Yes | Yes, but not in the NGO mode | Yes, but not in the NGO mode | Yes, but not in the NGO mode | Yes, but not in the NGO mode |
| Providers of STEM education from outside school system | Yes | Yes | No | No | Yes | Not quite |
| High bandwidth access to Internet in schools | High | High | No | No | No | No |

NGO = nongovernment organization; STEM = science, technology, engineering, and mathematics.
Source: Author.

As can be seen from Table 1, when benchmarked with Finland and Singapore, the state of STEM education in the four DMCs has room for improvement in a number of areas.

# Recommendations

Based on the findings of this study in the four DMCs, the following are the general recommendations.

**Improve students' interest levels in science and mathematics.** Survey findings indicate that students' interest levels in science and mathematics are not high in all the four DMCs. One way to improve interest levels of students in science is by exposing them regularly to enrichment programs (Caleon and Subramaniam 2005, 2007; and Dairianathan and Subramanian 2011). There are many such programs that can be conducted in schools and examples of these using commonly available materials, including:

    (i)    making a straw flute, and learning about pitch and amplitude of sound;

    (ii)   making a plastic parachute, and learning about design configurations of parachute, descent times of parachute, atmospheric resistance, and gravity;

    (iii)  studying catapult motion using rubber bands, Styrofoam cup, and ice cream sticks; and

    (iv)  exploring dynamics of motion by building a roller coaster with straws, cardboard, marbles, and a small cup.

Formation of science clubs, if not yet done, should be encouraged in schools. It would also help raise the activity levels of existing clubs. There is tremendous scope for diversifying the offerings in these clubs using commonly available materials as well as other low-cost resources. It will be helpful if this initiative is driven in each school by a results-driven young teacher who can also inject energy in these pursuits as well as galvanize students for the cause of science. Periodic talks by professionals, of which there is no dearth in the region, near the schools, and even by schoolteachers, can also be organized.

Research has shown that the role of the teacher is very important in getting students excited about science. That means there is a need to ensure that lessons are delivered in an interesting and well-resourced manner. Ultimately, this depends on the quality of the teaching workforce and the resources allocated for teaching subjects in STEM. Policy decisions on teacher recruitment, upskilling of existing teachers' competencies through professional development, and resourcing the schools are important.

**Ensure that STEM subject teachers attend regular in-service courses as part of their professional development.** Both teachers of STEM subjects as well as school leaders have flagged off the need for teacher professional development, and that the current levels are not adequate.

Some of the courses that take on board recent developments in the science and mathematics education literature can be on:

    (i)    using innovative approaches to teach physics, chemistry, biology, mathematics, and primary science;

    (ii)   finding new ways of assessing students' learning;

    (iii)  developing low-cost science and mathematics teaching aids;

    (iv)  designing and developing science enrichment programs; there are so much that can be done for the various topics in the sciences;

    (v)   using low-cost materials to conduct integrated STEM activities;

    (vi)  identifying misconceptions in the sciences;

(vii)   addressing students' misconceptions in the sciences through conceptual change interventions;

(viii)  updating pedagogical content knowledge in the sciences;

(ix)    conducting action research in schools;

(x)     using hands-on activities in the sciences and mathematics; and

(xi)    incorporating "nature of science" in STEM subjects.

An international consultant with expertise in STEM teacher education can be contracted to conduct these and other suitable courses for teacher educators in the four DMCs. To ensure a cascading effect, the teacher educators must be required to conduct these courses for schoolteachers in their countries. That means that the choice of teacher educators to attend these courses is very important. Since distance can be an issue in the country for teachers to attend in-service courses at designated training institutes, training can also be pivoted online to reach out to more teachers and thus allowing them to attend courses regularly.

**Revamp the school science and mathematics curricula.** While the current curricula in STEM subjects serve a useful purpose, survey findings highlight the need for some reform.

What is clear from the teacher survey and stakeholder observations is that the science and mathematics curricula need a revamp.[1] Explicit articulation of learning outcomes for each topic can better ensure breadth and depth to which a topic needs to be taught as well as be assessed. There is also a need to ensure that assessment goes beyond recall of facts. As far as possible, test questions need to be pitched at the different levels of the revised Bloom's Taxonomy so that students' learning can be assessed more rigorously.

**Improve preservice teacher education in STEM subjects.** Feedback has been given that the training programs teachers attended during their teacher preparation program are not quite up to expectations.

Teacher educators in STEM subjects need to undergo professional development programs that can upskill their competencies further and help to keep them abreast of the latest developments in leading teacher education institutes in the world. The emphasis needs to be on curriculum studies course in the respective STEM subjects; for example, physics, chemistry, biology, and mathematics; and on aspects that are informed by recent research developments. At the minimum, teacher educators need to be exposed to how programs are conducted in developed countries.

There is a need to revamp STEM education offerings at the preservice level so that trainee teachers are better prepared when they are deployed in schools. That means STEM subject staff need to enhance their pedagogies as well as introduce courses that are aligned with contemporary thinking in these subjects.

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[1]   There was no access to the school syllabi for the sciences and mathematics. As a result, it was not possible to make concrete recommendations on this count. It has not been possible to review the syllabus for curriculum study courses in STEM subjects in the teacher education institutes in the four DMCs and how these are enacted, owing to accessibility issues of the relevant documents.

A proper needs analysis must be conducted to see the strengths of existing offerings, how these can be improved further, the resources available for teaching, and how the competencies of staff can be improved further to address the new challenges of the emerging landscape in education in STEM subjects.

A tour of teacher education institutes in Finland or Singapore can provide useful perspectives on how teachers of STEM subjects in these countries are trained.

**Improve research expertise of academic staff of teacher education institutes.** Inspection of major scholarly databases in education in STEM subjects indicate a lack of publications in peer-reviewed international journals.

Short-term courses on how to conduct research in the following areas would be useful:

(i)    evaluate students' understanding of various topics in sciences and mathematics;
(ii)   identify students' misconceptions in various topics;
(iii)  explore students' views of various issues; for example, learning of the various STEM subjects, level of motivation, and what constrains them in their learning;
(iv)   conduct action research in schools;
(v)    explore teachers' views of various issues; for example, curriculum, assessment, learning climate in classroom, effectiveness of pedagogies used in classroom, and how to address declining interest in STEM subjects;
(vi)   analyze the syllabus from a research-informed perspective;
(vii)  study attitudes of students toward science and mathematics;
(viii) set questions at the higher levels of the revised Bloom's Taxonomy;
(ix)   use quantitative analyses of data; and
(x)    use qualitative analyses of data.

Staff teaching curriculum studies courses in STEM subjects at teacher education institutes need to be more active in research and publish research papers in international journals. This also helps them connect with the wider international community as well as leads to capacity building in various research domains.

Research can be done on issues in STEM education, students' understanding of various topics, teachers' and students' views about aspects of STEM education, gender effects, and effectiveness of STEM subjects curricula. Findings have translational significance with respect to practice, that is, how research findings can be acted on to improve classroom practice.

Some incentives for academic staff who publish research papers in international journals can be considered; for example, financial reward or additional salary increment.

**Establish science centers in the four DMCs to popularize STEM.** There are no science centers in all the four DMCs that are set up along classical lines, i.e., with a mission to popularize science and technology to the masses. Such science centers host exhibition galleries that contain many interactive exhibits catering to a multiplicity of themes in the sciences, offer science enrichment programs in various STEM subjects to school students, and regularly organize science promotional activities for the public.

Research in international journals have unequivocally established the important role that science centers can play in boosting science literacy levels, getting students excited about STEM, and contributing to the socioeconomic development of a country.

Contrary to popular notion, setting up of a science center is not expensive for a developing country, and it can be done using indigenous expertise and resources (Tan and Subramaniam 1998, 2003).

If the state can provide land and premises for free, exhibits in the sciences and mathematics can be fabricated in a cost-effective manner. Needed are wood, metal, and electronics workshops, which are available in all countries, as well as technical staff to operate these workshops. Such workshops are also available in the tertiary education and technical education institutes in a country and can be leveraged during the start-up phase. This helps to unlock residual spare capacity in these institutions for the further cause of nation building.

A small science center can be set up in the capital city in all the four DMCs using temporary premises leased from the government or given by the government. This can be done on a pilot basis so that relevant people can get a feel for the mechanics of what goes on into the setting up of a science center. This can be spearheaded by a young university academic in physics. Workshop facilities in the universities and technical institutes can be leveraged for the fabrication of interactive exhibits in the physical and mathematical sciences for a start.

The Exploratorium in San Francisco (United States) has made available in the public domain details of how to fabricate numerous exhibits in the sciences and mathematics. For example, The Exploratorium Cookbook Set (volumes I, II, and III) (Hipschman 1980) retails at just $350.

Scientific staff with qualifications in the sciences can be hired to come up with enrichment programs in STEM subjects that feature lecture demonstrations, laboratory activities, and exhibition tours for school groups. A few university academics can be seconded for a few years to get this moving. So many science centers have shared the programs they conduct on the web, and these can be referred to for replication, and with fine-turning for local contexts. The science center can also be the hub for makerspace activities and invention laboratories.

Setting up of science centers also leads to capacity building in a country, and promotes downstream economic activities. Based on the experience gained by the setting up of a science center in the capital city of the four DMCs, the experience can be replicated in other major cities in the country. In each city, it is better that a small-scale science center is set up and then is allowed to grow organically over time.

**Establish NGO-based scientific societies to boost activity levels for the cause of STEM education.** While there are no scientific societies that are set up in the NGO mode in all the four DMCs, these can be established as grassroots endeavors. However, they must be championed by prominent or influential scientists.

In the case of Singapore, the Singapore National Academy of Science and the 11 discipline-based scientific societies under its aegis have chalked up an impressive track record of promoting science and technology to students and the public (Tan and Subramaniam 1999, 2009) for more than 40 years.

They do not have premises and rely on a voluntary cadre comprising university academics, professionals in scientific disciplines, and others who are committed to the cause of science. This is a good model for emulation by the four DMCs.

Each city in the country needs to have an academy of science as well as scientific societies in all the major STEM disciplines, all set up along NGO lines.

It may be difficult for existing scientific academies in the four DMCs that are modeled along traditional lines to expand the scope of their mission objectives to address this challenge as it is not part of their mission objectives and may dilute their core mission. It may also necessitate amending their statutes. In the context of the importance of STEM education, they can consider reviewing their mission and vision for the cause of STEM education and see how they could further contribute toward this on a sustainable basis.

**Promote integrated STEM education initiatives through low-cost initiatives.** Teachers of STEM subjects have commented that they do not know how to teach integrated STEM lessons or conduct integrated STEM activities. They are not alone in this because, even in other countries, teachers of STEM subjects do not teach or conduct these. However, exposing students to integrated STEM activities is important.

Many developed countries promote integrated STEM education via quite sophisticated approaches. While there is nothing wrong with such an approach, it restricts replicability in developing countries owing to funding constraints, access to expensive setups, and enhancing outreach to as many students as possible.

It is possible to promote integrated STEM education via low-cost initiatives using materials and resources commonly available. With this, even research questions and hypotheses can be formulated for investigations by students under the supervision of teachers. Also, aspects of STEM can be infused in such approaches, each of which can be conducted over a half-day session. The challenge is to expose STEM subjects' teachers to these approaches so that, in turn, they can reach out to their students and provide them experiences in integrated STEM education. In due course, more advanced approaches can be infused, especially at higher levels.

It is not necessary to have integrated STEM as a separate subject in schools. The expertise necessary to conduct this subject is not quite there yet in the system as it requires domain expertise in four disciplines. It is better for schools to focus on developing student competencies, especially in the sciences and mathematics subjects, so that they are better primed for integrated STEM later. It is better for integrated STEM to be done via informal means; for example, as enrichment programs in schools or getting external agencies to offer these to schools.

In Singapore, integrated STEM is not offered as a subject in schools as the focus is on building competencies in the sciences and mathematics. Integrated STEM is left to the Singapore Science Centre to offer to schools. External vendors also offer such programs. As it is, schoolteachers in many countries generally have a heavy workload, and any further enlargement of their job scope can prove to be counterproductive to their core mission, which is to educate students in the key subjects.

**Drastically increase internet bandwidth in schools.** Teachers of STEM subjects as well as school leaders have cited slow internet connectivity in schools. This is one reason why teachers are not able to access internet resources to support teaching and learning.

There are ample internet-based resources for promoting the cause of STEM education in the English language; for example, simulations, animations, YouTube videos, text-based materials, and assessment of various topics. If these are harnessed judiciously, it can provide a tremendous fillip for the cause of STEM education in schools. Lack of adequate bandwidth in schools is an issue that has surfaced in the surveys.

In the short term, it would be more prudent for a central agency in the country to assemble resources from the web for each topic (with narration in local language), taking into consideration copyright issues, at different levels in the sciences and mathematics and distribute these to schools through suitable storage devices. However, a computer and a projector are needed to project these resources on screen in the schools.

Rather than landline-based access, it would be more prudent to opt for wireless access in schools. That means government support is important for upgrading router equipment in schools, setting up more base stations near schools, and installing next generation networks.

**Revamp learning materials in STEM subjects.** Feedbacks have been received from teachers of STEM subjects that the prescribed textbooks and other learning materials are generally not able to enthuse students in the learning of sciences and mathematics. A cursory examination of a few of the native language textbooks appears to underscore this assertion.

The physics, chemistry, biology, and mathematics textbooks used in Singapore schools can be a basis for reference when textbooks are revised during the next cycle. These textbooks draw on best practices in publishing as well as tailoring content to suit curriculum requirements in an interesting and appealing manner. Before that can be done, the syllabus should be reviewed to ensure that the topics are in sync with mainstream schools in other countries. A committee also needs to be formed to see what topics or aspects of the topics can be deleted or added in the process of revision.

**Improve assessment of student learning.** It has been noted that assessment of learning in STEM subjects during examinations is not rigorous. Before improved assessment can be implemented, teachers need to be trained on setting questions that promote thinking as well as features a good mix of the various hierarchical levels of the revised Bloom's Taxonomy. Teachers who need such training can attend professional development courses on how to set thinking questions in the sciences and mathematics. A policy change by the education authorities is needed if students' learning is to be rigorously assessed during examinations.

**Use survey instruments to study the state of STEM education in other developing countries.** Two survey instruments were developed for this study from scratch. One on views of teachers of STEM subjects on various issues related to STEM education, and another on school leaders' views of the education ecosystem. Both instruments exhibit very good psychometric validity and reliability. The foremost advantage of these instruments is that it can provide ground-level feedback from

stakeholders in the system. Additionally, questions related to perception ratings of a few issues as well as the open-ended questions in the survey instruments can provide additional opportunities to surface other feedback. These instruments can be used to study the state of STEM education in other DMCs as well as the views of school leaders.

## Future Actions

Below are some recommendations for future actions.

**Organize workshops.** For each of the recommendations given in this report. Workshops can be organized so that the full import of the recommendations can be elaborated further to stakeholders. This platform can be useful also to address queries and clarifications from stakeholders so that they know what exactly are needed to implement the ideas suggested. A day-long workshop would suffice for a start for each of the recommendations, but there should be a sustained period of online support for the timely realization of the recommendations.

For in-service training of teachers, each of the topics suggested needs about 3 days' training—1 day for instructor delivery, another day for participants to work on their assignments, and a further day for presentations and feedback. These workshops can be done in collaboration with the respective ministries of education in each of the four DMCs. The 3 days can be spread over a period of 3 weeks. The choice of participants for each workshop is critical. The participants should be a mix of staff from the ministries of education, teacher education institutes, experienced teachers of STEM subjects from different levels, and other stakeholders. It should be limited to about 20 persons for effective interactions. These participants should be selected after careful screening and ensuring that they would be able to drive the necessary change in the system through their energy and drive. More importantly, they should also conduct these workshops to others in the fraternity so that there is a cascading effect in the community.

**Setup of science centers.** Science centers can create additional contributors for the cause of STEM education in a country. A high-level national committee can be set up to realize this goal. Members of the committee can be drawn from universities, polytechnics, technical institutes, schools, ministries of education, and industries. The technical expertise and resources available in tertiary institutions provide ample opportunities to amortize latent potential for fabrication of exhibits and conceptualize science enrichment programs. These initiatives tap on the propensity of indigenous expertise and resources to drive the agenda. Some seed funding to spur the driving of these initiatives can be helpful.

The setting up of NGO-based scientific academies needs to be considered as it can promote the opening of yet another channel for the cause of STEM education. This can also be an avenue to galvanize the scientific community for the cause of nation building. Some seed funding for this effort can reap good dividends in the medium to long term. It is desirable for stakeholders to identify a few influential scientists to spearhead this effort.

**Provide teacher education.** An important weakness identified in this study is the suboptimal levels of output in educational research in STEM subjects in the teacher education institutes in the four DMCs.

Educational research is driven by teacher education institutes and is not something that can be achieved in the short term. Expertise in educational research is important, from a research-informed perspective, in identifying strengths and weaknesses in the education system, effectiveness of STEM subjects teaching in schools, effectiveness of intended and enacted curricula in achieving educational objectives. The state needs to send suitable top graduates to overseas teacher education institutes for doctoral studies in STEM education; for example, to Finland, Singapore, the United Kingdom, and the United States. Exposure to overseas doctoral education would be a good way to promote diversity in staff backgrounds as well as gather best practices from overseas teacher education institutes. Funding can be addressed by a model based on contributions from national and overseas teacher education institutes. Research skillsets of existing doctoral staff can be upgraded through targeted interventions that entail a mix of research-based workshops and assignments supervised over a semester.

A series of workshops on integrated STEM activities need to be conducted for teachers of STEM subjects so that they can get experiences on low-cost approaches in this regard as well as percolate these activities through the school ecosystem. Some seed funding from ADB can be helpful in this regard.

**Revamp teacher education institutes.** Teacher education institutes in the four DMCs need further revamping with respect to curriculum studies courses in STEM subjects. This needs careful review, as proper needs analyses have to be conducted through surveys and stakeholder discussions. Some insights have already been obtained in this study and can be a useful start to enhance further the efficacy of the offerings, including training of preservice teachers. The experiences of Finland and Singapore suggest that recruitment of trainee teachers as well as academic staff of teacher education institutes needs to be very stringent if the wider objectives of education need to be realized in good measure. Rigorous staff appraisal procedures need to be developed so that a culture of excellence can be promoted.

**Increase connectivity.** Internet connectivity has been singled out by both teachers of STEM subjects and school leaders as a constraint that comes in the way of effective lesson delivery in the classroom. While this may take some time to sort out, in the interim, there is nothing to stop the formation of suitable committees from mining the rich resources of the web. For example, identifying suitable YouTube videos, simulations, animations, of short durations on various topics in the sciences and mathematics for each grade level, storing these in suitable digital formats (subject to addressing copyright issues where applicable), and making these available for schools in the country. Low-cost computers and projectors should be made available to schools to share such resources during lessons.

For example, the following YouTube videos can be used to complement the teaching of concepts in the relevant topics in the sciences:

    (i)    https://www.youtube.com/watch?v=uixxJtJPVXk (Reactivity of Group I metals in Chemistry), and

    (ii)    https://thekidshouldseethis.com/post/reversing-arrow-illusion (Lateral inversion in Physics).

Each committee can comprise relevant teachers of STEM subjects and an ICT expert. The work can be completed in a couple of months since they focus only on their subject and grade level. Needed are narrations in the native language for each of the resources. Some seed funding can help jump-start this initiative and reiterate to stakeholders the importance of such cost-effective endeavors to circumvent constraints and limitations. The proposed interim solution can be a way to move forward.

## Conclusion

The four DMCs are well-positioned to ramp up education in STEM subjects in schools. School leaders, teachers, and policy makers recognize the need for the country to be strong in STEM education. This is a very gratifying development, and augurs well for the future of the country.

There is a need to recognize areas identified for improvement in this study and work toward addressing these. More importantly, it is first necessary to enhance science and mathematics teaching and learning as well as assessment in schools before focusing on integrated STEM education.

STEM education in a country cannot just be the responsibility of schools. Other stakeholders need to come in or be incentivized to come in through policy initiatives or via collaborations. Integrated STEM education is best promoted via informal science education, either by schools as enrichment programs or by institutions dedicated to science popularization.

It is not necessary for a STEM subject to be introduced in schools when levels of science and mathematics need improvement. In fact, many countries do not have a STEM subject in the school curricula. However, there is a need for students and teachers to be exposed to low-cost initiatives that can promote integrated STEM education.

# EDUCATION TECHNOLOGY

## Background

A common misconception is that education technology (EdTech) covers only the use of technology in teaching and learning. Yet education systems consist of far more than that which goes on between teachers and students. Thus, the broader understanding of EdTech is to include the use of technologies, at any point, in an education system with the pursuit of improving components of the system, i.e., teaching and learning, assessment, human resources, communications and outreach, and data management.

EdTech traces its roots back to cave paintings as a modality to share knowledge and preserve culture through generations. In the modern era, EdTech is thought of as a mix of ICTs. In this document, EdTech is dated to the advent of radio and, soon after, the advent of film. As a teaching tool, film took off with World War II military. It was used to give visualization of knowledge to large groups simultaneously. In the past 20 years, EdTech is thought of as the use of devices, hardware, and software that help in the delivery of more enriching knowledge transmission. A good definition that can be used comes from Wikipedia: "[Edtech] is the combined use of computer hardware, software, and educational theory and practice to facilitate learning. Educational technology creates, uses, and manages technological processes and educational resources to help improve user academic performance."[2]

## Introduction

Many years of research show that technology does not necessarily result in fundamental improvements to educational practice. There are many examples of fast-improving education situations. Overall, however, the world still relies on a model of education fostered about 100 years ago with the advent of mass public education systems.

EdTech represents a path forward. Yet, in the past few decades, EdTech has had a slow start and lackluster support in changing, at the systemic level, how education is delivered. The application of new methods, out of necessity, must be approached with strategy rather than haphazard approach.

The country analyses pave the way to better understand not only the current situation; they also create a baseline of understanding that can lead to longitudinal data, which then lead to better strategy in the approach to solving learning crisis.

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[2]    https://en.wikipedia.org/wiki/Educational_technology.

Below are a few key ideas to consider as principles for national deployment.

(i) **Education before technology.** The major failing has been a lack of understanding in that the focus needs to be on the learner's interaction with technology, not the technology itself.

(ii) **Data-driven decision making.** The inclusion of data analytics techniques in education could be a game changer in terms of developing adaptive (customized) learning, and systemic planning for strategy.

(iii) **Scalability and replicability.** EdTech must focus on return-on-investment in the sense that the focus is to constantly strive to prove scale and replicability in bringing down costs, while engaging learners in new and innovative ways.

(iv) **Inclusion.** As access to information has become more open, it is also essential that EdTech provide pathways that lead to equalization and democratization of education for all groups, marginalized or resource-rich.

ADB has a deep interest in improving the quality of education in its member countries through technical assistance and support through grants and loans on a wide variety of social development projects. In the past few years, countries have taken a greater interest in how to best adapt learning systems to improve through modern EdTech.

The coronavirus disease (COVID-19) pandemic has been a stark reminder and eye-opener to ADB member countries that lack of strategic investment in EdTech has resulted in many education systems unable to cope with rapid changes that are necessary to ensure that children remain engaged in studies.

The principal purpose of this project[3] funded by ADB is multipart, and analyzes the following:

(i) **Current state:** To explore and present the state of EdTech in four DMCs of Bangladesh, Cambodia, the Kyrgyz Republic, and Uzbekistan.

(ii) **Replicable methods:** To develop replicable toolsets and methods that could be deployed anywhere around the world to research and measure the situation of EdTech in any country or region.

(iii) **Provide recommendations:** To develop recommendations based on the research conducted that may lead to more strategic deployment of EdTech interventions.

(iv) **Share results:** To allow ADB, other development partners, and governments to develop better interventions based on the findings.

## Project Description

### *Project Objectives*

This four-country study aims to produce a model for replicable country situation analysis of EdTech readiness. The selection of four pilot countries was used to develop tools, processes, procedures, and test such methods to develop a viable, replicable, and scalable model of national EdTech assessment. The tasks based on mapping and analysis of the current situation on EdTech and the needs on using it in public education, specifically in teaching and learning in schools, will help conceive appropriate, timely, and effective interventions at the country level.

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[3]  The project refers to the four country studies on situation analysis of EdTech.

### *Country Situation Analysis Reports*

The main output of the project has been presented through country-level situation analysis outlining the EdTech condition in each of the four countries. The reports are structured to follow the five pillars and domains:

(i)    **infrastructure**, including quality, coverage, and accessibility;

(ii)   **government**, legal environment of ICT for education, government policy, planning and activities.

(iii)  **schools and teachers'** situation in schools including systems, teachers' capacity and skills, digital content, and curriculum (subjects) quality, outcomes, and assessments;

(iv)   **parents' and students'** situation, including accessibility, inclusivity, and digital literacy of the learners; and

(v)    **providers**, the competitive landscape of providers, including systems, content, technological integration services, and innovative solutions that support EdTech-based learning.

## Findings

The four-country study resulted in numerous findings per each of the 20 areas under investigation. Through a process of amalgamation across the four countries, it was agreed to focus on two key findings per each of the four subareas under the five domains studied, thus resulting in about 40 key findings per country at the minimum.

The authors have analyzed more than 160 report findings, while categorizing them into key unifying themes that relate to areas of concern for EdTech development in each of the countries. An additional highly developed country was added to provide perspective and serve as a benchmark and goal.

Through the research conducted in each of the four countries, an index of extensive findings (what has been learned—issues, challenges, and gaps) was developed. The findings were reinforced through direct researched evidence and supported with suggestions to alleviate the challenges presented.

Eleven key unifying themes (areas of priority as identified in the research) across the four countries studied have been identified and used as a basis to draw comparison across the four countries while linking to our benchmark country of Singapore. Those EdTech themes are

(i)     digital content creation,

(ii)    capacity building,

(iii)   data-driven decision making,

(iv)    devices (accessibility),

(v)     platforms/e-learning systems,

(vi)    governance (policy/planning),

(vii)   connectivity (internet),

(viii)  telecom/broadcasting,

(ix)    electricity availability,

(x)     emerging technology, and

(xi)    EdTech partnerships.

The following is a set of statements drawn from extensive mapping through findings, evidence, and suggestions (recommendations will be presented in the following unit).

(i)     All four countries lag the benchmark country (Singapore) in terms of the 11 themes considered. Singapore is recognized as a leader in Asia, and thus this was not unexpected. Yet, in saying this, it may be useful for each of project countries to examine Singapore as a successful model.

(ii)    The four project countries are underdeveloped when examining the following key themes: digital content creation, capacity building, data-driven decision making, devices (accessibility), governance (policy/planning), connectivity (internet), electricity availability, and emerging technology.

(iii)   The four countries seem commonly more developed under the key theme of 'telecom/broadcasting.'

(iv)    Connectivity is a major issue across all the four countries, especially in remote areas.

(v)     Two of the key gaps across in need of scaled intervention are capacity building and data-driven decision making. Teachers throughout the project country are not confident in the goal to modernize teaching/learning and there is little use of sophisticated management information system to drive decision making.

(vi)    All four countries are at the very early stage of development on emerging technology and EdTech partnerships.

In the following section, many of the key themes will be repeated in an attempt to offer actionable recommendations.

## Recommendations

Table 2 presents recommendations that can be used by any national education authority to ensure proper deployment of EdTech. Table 2 is directed on recommendations for the national education authority. Appendix 2 provides additional recommendations for infrastructure and provider domains are given, yet not described in such detail as the target of the research is on national education authorities. Nevertheless, it is important to understand that the other domains interact and are intertwined in the following eight high-level recommendations.

**Develop a comprehensive national plan on EdTech capacity development that involves close partnerships with key experts, development agencies, schools, teachers, and local providers, targeting teachers, teacher educators, education officers, and parents.** Inefficiency is a result of improper training. Poor training methods, poor materials, training the wrong people, duplication, and lack of scaling are among the many reasons for training failure. Far too often, EdTech training is conducted without proper systemic strategy in place. There are three key variables in assuring that a target audience reaches expected learning outcomes: (i) digital access, (ii) skills, and (iii) literacy. The following graphic gives detailed explanation of the taxonomy and shows relationship to Bloom's Taxonomy for reference (Figure 1).

It is expected that education authorities design a comprehensive national plan on EdTech capacity development, targeting teachers, teacher educators, education officers, and parents. It is essential that everyone working in the education system can contribute to a fast-digitizing field that requires ubiquitous participation. A well-thought out plan that is inclusive and thorough will be essential to a transformative shift. Such plans do not require that every person is trained. Instead, the focus must be assessment through showing performance at agreed levels.

**Table 2:** Synopsis on Education Technology Delivery through the Ministry of Education

| | Theme | Recommendations to Ministry of Education |
|---|---|---|
| 1 | Capacity building | Develop a comprehensive national plan on EdTech capacity development that involves close partnerships with key experts, development agencies, schools/teachers, and local providers, targeting teachers, teacher educators, education officers, and parents. |
| 2 | Connectivity | Develop a national strategy to ensure that ubiquitous broadband internet is freely available to all students, teachers, education officers, and their respective institutions. |
| 3 | Content | Develop a comprehensive content development strategy that ensures focus on learning objects, distributed content creation, and interactivity content, while linked to the national curriculum. |
| 4 | Data | Design, develop, and deliver a unified web-based education data system that effectuates a robust data-driven decision-making culture. |
| 5 | Devices | Ensure focus on appropriate EdTech devices for schools that highlight low cost, low energy, and low maintenance. |
| 6 | Governance | Governments must rethink how they advocate EdTech interventions to become more decentralized, provide local funding, and build a wide scope of supporting partners (local, national, and international partners). |
| 7 | Platforms | Develop interoperable web-based platforms that are user friendly; interactive; and encourage decentralized contribution of courses, content, and assessment. |
| 8 | Standards | Develop and disseminate detailed ICT competency standards for teachers, teacher educators, education officers, and students. |

EdTech = education technology, ICT = information and communication technology.
Source: Asian Development Bank.



**Figure 1:** Key Variables in Digital Capacity Mapping
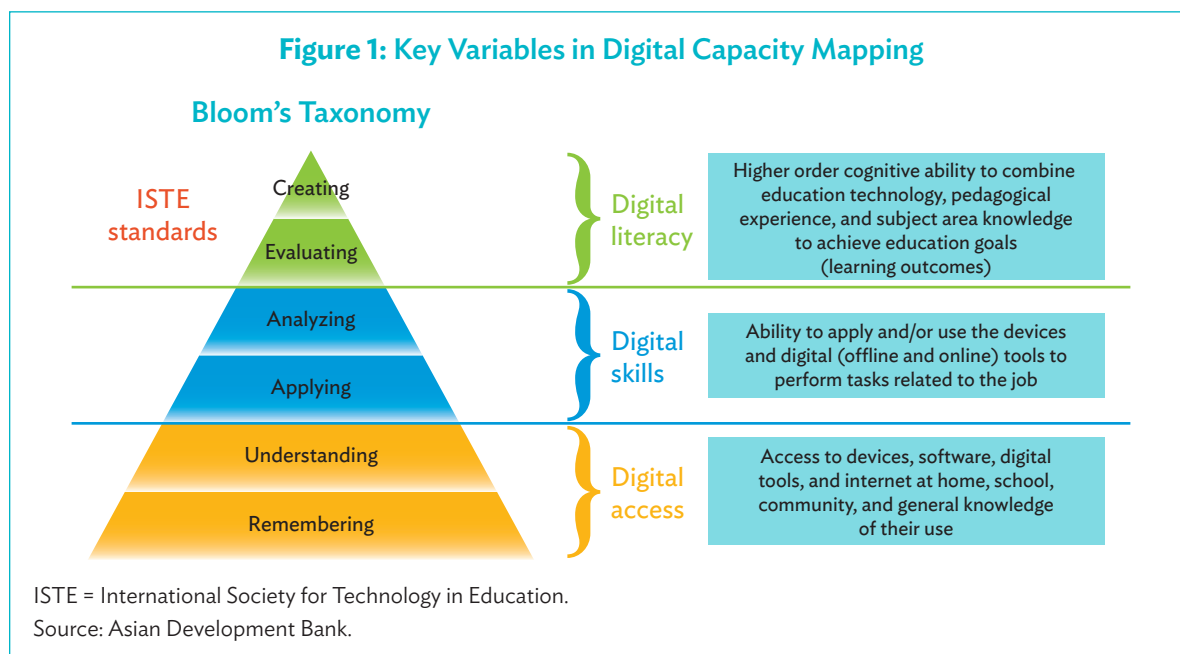
ISTE = International Society for Technology in Education.
Source: Asian Development Bank.

**Develop a national strategy to ensure that ubiquitous broadband internet is freely available to all students, teachers, education officers, and their respective institutions.** As nations digitize, we realize the efficiencies in automation not only in teaching and learning but in data collection, communications, and community outreach. It is imperative that education systems provide ubiquitous internet access. Connectivity from the perspective of the internet is considered a game changer in reaching learning outcomes, communicating, and sharing information, and collecting data, thus developing strategy for systemic improvement. Providing internet connection may be among the greatest problems that an education system may meet. It is complex, expensive, and the devices required to maintain system are prone to failure. Yet, of the various forms of connectivity (i.e., local area network, file sharing), there is no greater possibility to transform a nation and an education system. During the COVID-19 pandemic, nations around the world that quickly realized their failures to plan for school connectivity ensured that all teachers have access at school and out of school while students can access learning materials and education officers able to monitor and plan.

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### Box 1: Giga—Connecting Schools across the World

Since 2019, the International Telecommunication Union and the United Nations Children's Fund have formed a partnership called "Giga Connect" with the aim to bring internet to all schools the world over. This initiative is "[develop] a comprehensive strategy to: map unserved schools; develop better and/or new financing programs to bring together diverse public and private funding; initiate large-scale procurement and improve transparency in monitoring."

Numerous countries around the world have engaged their national telecom companies to establish special data pricing for fixed and mobile internet packages for teachers, students, and schools. For example, in California in the United States, during the coronavirus disease (COVID-19) pandemic, Google has given away 100,000 free Wi-Fi hotspots for households that lack internet and have students that must get online for education purposes.

Source: Giga Connect. https://gigaconnect.org/.

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**Every country should develop a comprehensive content development strategy that ensures focus on learning objects, distributed content creation, and interactivity content, while linked to the national curriculum.** As has been examined during COVID-19, many countries have rushed to develop digital content[4] to meet the needs of teaching and learning through broadcast and/or internet delivery modes. The failure in such efforts has been a lack of widespread capability to develop digital content that meets the needs of the learners while supporting teacher's capability to better convey ideas. The transformation needed involves quality of content, deeper understanding of how the content may help reach learning objectives, and technical aspects in content storage and delivery. Suggested corrections to content development that must be managed and included in strategy and plans are in Table 3.

**Design, develop, and deliver a unified web-based education data system that effectuates a robust data-driven decision-making culture.** The success of the education sector is based on strategic

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4    The term "content" can refer to a document/writing or to media. In this context the author is referring to digital media used in teaching and learning.

**Table 3:** Key Aspects on Digital Content Transformation

|   | Topic | Description | Rationale |
|---|-------|-------------|-----------|
| 1 | Learning object | A modular resource, usually digital and web-based, that can be used and reused to support learning activities. | Learning content that is too complex in size (time, quantity), and/or learning objectives covered cannot be easily adapted, reused, or shared. |
| 2 | Distributed content creation | A process of developing content through decentralized modalities mainly that included various actors in the education system (i.e., students, teachers, and creators). | Traditionally, education content (i.e., textbooks) are created by central authorities through curriculum material developers. For digital media, which is time intensive, it is best to devolve tasks to as wide a scope of actors as possible. |
| 3 | Interactive content | Content that is created to capture user attention and encourage action. | Brings ways to engage the learner, enticing excitement, at the same time improvising on learning experience by increasing retention. |
| 4 | Curriculum linked | Process of assuring that the content is linked to learning objectives and activities as outlined in the curriculum. | Materials not properly aligned to the process of learning delivery will easily be misused or lost as the connection to objectives and activity may not be made. |

Source: Asian Development Bank.

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**Box 2:** Comprehensive Online Education System Data Portals

With the advent of digital systems in data collection and especially web-based programming, it has become possible to move education data collection to online systems, thus leapfrogging the laborious process of data collection, amalgamation, sorting, and basic analysis. What used to take months or years is now available through automated systems like https://www.OpenEMIS.org. In a mere fraction of the time, it allows automated and real time data collection. Currently, a growing list of countries are using the free or paid version of this software to jump-start data collection, leading to more strategic decision making predicated on evidence.

Source: OpenEMIS. https://www.openemis.org.

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planning that is predicated on data-intensive decision making. EdTech supports education systems by providing automated data systems over traditional paper-driven data collection. Education system data are collected primarily at the school level and feeds into at least two system types (Box 2):

(i)   **School information system** (SIS): higher frequency data collection, including all systems that are needed to manage day-to-day operations of a school.
(ii)  **Education management information system** (EMIS): low frequency yet large-scale data collection with the express purpose of providing data sets used specifically for national education system planning.

SIS and EMIS are often thought of as one system. However, typically, strategic planning of an education system does not require high frequency data. Thus, data such as daily student and teacher attendance is generated at the SIS level and, for planning purposes, remains at the school or administrative level

just above the school. In contrast, EMIS data are typically collected once or twice a year and serves the purpose of assisting national planning. It is important to understand and plan for data collection at the right entry point, of the right frequency; and ensure utmost safety and security of all user data.

**Ensure focus on appropriate EdTech devices for schools that highlight low cost, low energy, and low maintenance** (Box 3)**.** The world of EdTech is full of failed examples of content creation that does not meet learner needs, device deployment that fails soon after placement, and a lack of capacity to integrate. The basic premise is a rush to provide solutions without having researched the problem. Bangladesh is a country of extremes, and thus a one-size fits all solution to device deployment stands a high chance of failure. An in-depth study before device selection will ensure that robust, low-energy, low-cost, and low-maintenance devices are selected for the education sector.

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**Box 3: Ensuring Appropriate Education Technology is Applied**

The concept of appropriate technology for schools is a multipart issue that covers, but not limited to, affordability, reliability, and potential to meet educational aims. In 2005, the One Laptop Per Child[a] project was born to meet all three of those objectives. At that time, a laptop computer costs $1,000 or more. Thus, they set the goal of $100 per laptop, ensuring robust child-friendly devices loaded with software that focused on learning outcomes. Since that time, education technology has changed immensely. Yet, it is a must that education systems focus on those three precepts to ensure proper selection of devices as options are great and the cost of choosing the wrong option is great.

[a] Note that the initiative is controversial.
Source: OpenEMIS. https://www.openemis.org.

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As an example, there are many types of computers available in all sorts of sizes, shapes, capability, and cost. Yet, for each environment and application, there are only a few that fit for a particular purpose. The availability of low energy-consuming computers that consume a fraction of electricity of devices a few years back, yet with sufficient speed and low-maintenance, are readily available yet very rarely deployed because of a lack of research on appropriate devices. Similar to modern smartphones that have no moving parts, require minimal maintenance, do not dissipate excessive heat, and seem to work in tough environment without fail, there are also what are called single board computers that are based on the same concept. At $35 per single board computer, the Raspberry Pi is such a computer developed specifically for education. Devices such as the Raspberry Pi must be considered for large-scale deployment and the ability of the system to reach its goals in an appropriate fashion

**Governments must rethink how they advocate EdTech interventions to become more decentralized, provide local funding, and build a wide scope of supporting local, national, and international partners.** Enthusiasm for digital inclusion takes on a local meaning when members of the community feel that they are part of the discussion. Far too often, EdTech is seen as a top–down endeavor where national governments control content, devices, schedules, and platforms.

The concept of local ownership became popularized through early work on climate change and the 1992 Rio Earth Summit, where considerable thought was given to local inclusion to foster broad change and has been successfully applied throughout all development endeavors. The concept makes sense in terms of bottom–up approach to environmental awareness. With EdTech, it is also crucial to ensure that communities are actively involved in devices, connectivity, mentoring, and maintenance.

A key finding in the research has been particularly on the lack of local support to maintain devices. This has been found to be a major hurdle in household purchases. Broken TVs, malfunctioning smartphones, and poorly performing computers are just the start in complexities that families meet in owning complex digital devices. Thus, governments must empower communities to collaborate in addressing the challenges they face and, at the same time, link local to national and international partners for maintenance, mentoring, and training.

**Develop interoperable web-based platforms that are user friendly; interactive; and encourage decentralized contribution of courses, content, and assessment** (Box 4)**.** A key failure in provision of online learning has been similar to the previous suggestion in overly centralized platform design and development. There are many issues with such platforms the world over. The student and teacher are often confronted with failures in platforms, they know the issues best, and can provide solutions for improvement. Some brief suggestions are:

(i)    **Interoperable.** Platforms should be able to "speak" with each other, sharing data and content (i.e., learning management systems to repository).
(ii)   **User friendly.** Use design thinking to ensure that the users' needs are put front and center.
(iii)  **Interactive.** Dynamic content that engages the user ensures user feedback loops and assessment.
(iv)   **User contributions.** Involve the user through contribution of ideas, suggestions for improvement, and content.

Learning platforms must be seen as holistic in that they grow, adapt, and change to meet the needs of the country. For that, copious user feedback, user ownership, and design thinking must be integrated at all stages for scalability to work.

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### Box 4: Deployment Risk Reduction through Proven Strategy

Modern schooling is no longer thought of as what happens in school alone. It is now commonly understood that great schools engage the community on a wide variety of school issues. The world over, schools are building websites, creating social media networks, and conducting town halls to ensure that their communities stay engaged and grow with the school as a partner in learning. Knowing full well that education technology is successful only through holistic participation, in 2006, major world development partners began discussions on Digital Principles, which ended up being nine statements or principles to guide the development of information and communication technology and improve on success rates. Embedded at the core of these principles is a common thread on engaging the target audience in design, development, and implementation of information and communication technology projects. Of specific note is the following principle: "Understanding the Existing Ecosystem—Well-designed initiatives and digital tools consider the particular structures and needs that exist in each country, region, and community."

Source: Principles for Digial Development. https://www.digitalprinciples.org.

**Develop and disseminate detailed ICT competency standards for teachers, teacher educators, education officers, and students** (Box 5)**.** The shift to modernized education delivery has been hastened through the COVID-19 pandemic as governments around the world have been caught off guard in providing education continuity. Crucial to the shift is a move to incorporate EdTech and especially distance learning modalities at rates never seen before. Yet, a key aspect of the shift that is being overlooked is the understanding that traditional classroom-based education, and those that are needed to succeed in distance modalities, are fundamentally different.

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**Box 5: Shift to Flexible Learning through the Use of Online Learning Platforms**

Over the past few decades, interest in online e-learning platforms, including learning management systems and educational content repositories, has grown immensely the world over. Through open-source offerings, there are numerous exceptional learning management systems offerings.

At the top is Moodle, with millions of actively installed instances and countless millions of users. The space of at-cost and freely accessible systems is full of many stellar examples. As learning focuses more on discrete skills and lifelong learning goals, more attention is being paid to platforms like Skill Share and Alison. The strength of such systems lies in their ability to attract students, developers, and facilitators the world over, while focusing on common courses that are scaled beyond local needs. Built in this model is continual improvement of the platforms to ensure that student and teacher needs are met in providing better software, more interactivity, and reaching learning outcome more effectively and efficiently.

Source: Asian Development Bank.

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For this reason, distance education is based on competency-based teaching and learning modalities that feature performance at the core of the transformation. In contrast, in traditional education methods, physical presence is used to measure student development based on attendance, participation, and other common modes. Table 4 outlines the fundamental differences between traditional education delivery and that of competency-based delivery.

**Table 4: Differences between Traditional and Competency-Based Education**

| Traditional Style[a] | Competency-Based |
|---|---|
| Based on knowledge and disciplinary skills | Based on practical learning |
| Schooling processes are central | Learning processes are central |
| Teacher-centered | Facilitator-centered |
| Students are passive learners | Students are active learners |
| Discrete disciplines | Interdisciplinary |
| Discrete skills practice | Integrated skills |

[a]  Traditional learning is also referred to as "time-based" because the focus is on delivery of learning through units of time. In comparison, competency-based learning is not focused on delivery with a unit of time, but based on performance measurement as the unit of success.
Source: Asian Development Bank.

At the core of competency-based delivery is clarity on expected skills and capabilities through mapping of what are referred to as competency standards. The standards are discrete statements referring to the level of performance that is expected based on a domain or category that identify student outcome. Therefore, the fundamental shift that must happen to enable EdTech diffusion is development of competency standards across the education system.

For EdTech and ICT abilities, every country should formulate ICT competency standards to provide pathways that define what is expected of students, teachers, head teachers, teacher educators, and education officers. The current best standard for such competency standards comes from the International Society for Technology in Education, where they have mapped out standards for teachers, educators, students, and a range of other professionals. Those standards can be adopted, adapted, and translated for use in any country, thus forming a clear pathway for expectation and capacity development.

## Future Actions

The following provide some recommendations for future actions.

**Provide a mapping of key informant awareness on EdTech areas throughout the country.** The value of ownership and awareness has been a strong finding throughout the research. While perception is not a measurement of availability or quality, it is important in that it gives sense as to where the country stands in the key areas measured in EdTech readiness. The result may be an EdTech readiness index that allows cross-country comparison, over time.

**Provide rapid country situation analysis so that many countries can report their status quickly and efficiently.** The tools, methods, and the core taxonomy developed in this study may be duplicated. The body of knowledge generated from such studies would prove immeasurable in providing more in-depth and thorough understanding of EdTech, while providing a road map both at the country level and internationally, to move forward in more strategic directions.

**Develop general standards and tools that can be used rapidly in any country.** At the core of EdTech is a fundamental change in the way we approach education. Education systems have realized through the recent pandemic how crucial it is to be prepared for a wide range of abrupt changes to how schooling is delivered and how education is managed. At the core is the necessity to ensure that every country has a clear insight on what they expect from students, teachers, teacher educators, head teachers, and education officers in the form of digital skills and literacy. ADB and development partners can design easy-to-use tools to help countries ease the shift to analysis—designing, developing, and implementing ICT competency standards for all key target groups.

During the pandemic, the weak link has been inability of education officers to understand the scope, depth, and breadth of the need for EdTech at the access, skills, and literacy levels. Countries have seen great loss because of ineffective materials and misunderstandings in digital access at all key points in the system. The greatest issue has been the lack of capable thinkers throughout the system to realize issues and effectuate proper change. This is because of a lack of continual professional development pathways to key EdTech knowledge. To effectuate lasting change, all countries must ensure ubiquitous capability

among education officers, teacher educators, and teachers. Figure 2, based on the four-country study, lists some of the key areas of deep knowledge that is often missing in countries and thus results in improper investment.

**Figure 2: Missing Keys to Education Technology Capacity**

- Connectivity
- Digital learning materials
- Online assessment
- EdTech policy
- Institutional capacity
- Digital literacy for teachers
- Pedagogical use of technology by teachers
- Devices

EdTech = education technology.
Source: Asian Development Bank.
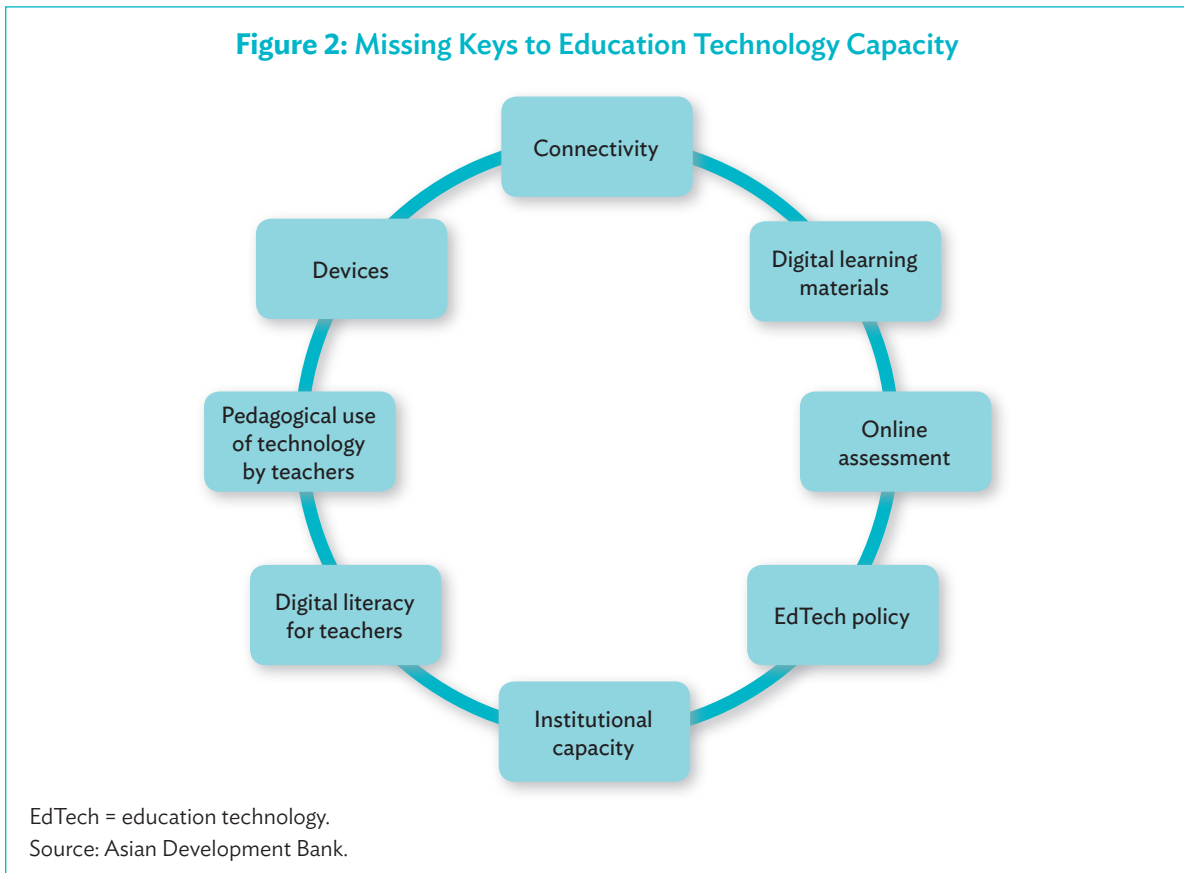
# METHODOLOGY

## STEM Education

To assess the readiness of the four developing member countries (DMCs) in science, technology, engineering, and mathematics (STEM) education, the following key questions guided this project:

(i)   What is the current situation with respect to STEM education in the areas of school education and preservice teacher education in the four DMCs?

(ii)  What are the views of STEM teachers and school leaders in the four DMCs on how the various stakeholders and supporting infrastructure are contributing toward the cause of STEM education?

For each of the DMCs, the state of STEM education was explored, and a comprehensive report has been prepared.

### *Methodology*

Curriculum and policy documents can provide only limited insights on a country's education system and its preparedness to address the challenges of the 21st century. There is a need to reach out to stakeholders in the country—especially science and mathematics teachers and school leaders—to hear their views on what is working and what needs improvement in schools. That is, a ground-up exploration can yield significant insights that may not be captured by other means.

Owing to the paucity of relevant data on the state of STEM education that goes beyond the collecting of information that can be obtained from the respective education authorities in the four DMCs, this study adopted a ground-up approach to obtain salient data. In this context, the design, development, and administration of two survey instruments formed the principal approach.

The advantages of such an approach are:

(i)   It allows for the exploration of factors that are perceived to be important in such a study; for example, syllabus and assessment in the case of STEM education, and professional development of teachers and linkages with education authorities in the case of school leaders.

(ii)  The responses from targeted respondents on the various aspects explored in the surveys can provide reliable and accurate information and data.

The quantitative analyses of data from the surveys were complemented with other approaches to triangulate data. These will provide additional level of robustness for the data obtained. In support of this, perception ratings, open-ended questions in the surveys, as well as interviews of stakeholders were used.

Thus, a mix of qualitative and quantitative approaches were used in this study.

Two survey instruments were developed for this study.

(i) One survey explored the views of teachers of STEM subjects on various aspects related to STEM education. A preliminary version of the instrument was developed by reference to the psychometric literature. Seventy-six survey items parked into 12 subscales were developed. It was ensured that each subscale had at least five items, in accordance with psychometric best practices. The various subscales can be seen in the section on findings. A 5-point Likert scale ranging from strongly disagree (1) to strongly agree (5) was used. In addition, perception ratings by the respondents on a few issues were provided. Also, four open-ended questions were used. The open-ended questions served the purpose of ferreting out further views of the respondents on STEM education that may not be captured accurately by the survey. The survey form was sent for validation to the project team. One member responded with comments, while the others had no comments. Based on this, the survey instrument was slightly refined.

(ii) Another survey instrument sought the views of school leaders about aspects of the education system. A preliminary version of the instrument was developed by reference to the psychometric research literature. Thirty-two survey items parked into five subscales were developed. It was ensured that each subscale had at least five items in accordance with psychometric best practices. The various subscales can be seen in the section on findings. A 5-point Likert scale ranging from strongly disagree (1) to strongly agree (5) was used. In addition, perception ratings by the respondents on a few issues were provided. Also, four open-ended questions were used. The open-ended questions served the purpose of ferreting out further views of the respondents on the education system that may not be captured accurately by the survey. It was sent for validation to the project team. One member responded with comments, while the others had no comments. Based on this, the survey instrument was slightly refined.

Both instruments were in English and were translated into the respective native language except for the respondents in Bangladesh. Where appropriate, the survey items were slightly refined for local contexts. For example, in the English version, the term "Ministry of Education" was used, while in the Uzbekistan version the term was amended to "Ministry of Public Education." The instrument was also checked for fidelity of translation to ensure that the intent envisaged in the English version is also captured in the native language version.

To get a better understanding of the thinking of stakeholders, key people such as curriculum specialists, policy makers, and STEM teachers were interviewed. Questions were developed to probe aspects relevant to the scope of this study, especially on what is working and what needs improvement in the education system. The interviews were done either via face-to-face session, online, or phone, depending on the country.

Owing to the relatively large number of survey items, it was necessary to reach out to a suitable number of respondents. The rule of thumb in the psychometric literature is that the ratio of samples to survey items should be at least 10. This was fulfilled in the present study for each of the DMCs (Table A1.1). For each DMC, the number of respondents who completed the surveys are.

**Table A1.1:** Sample Sizes for Survey Instruments in Each Developing Member Country

| Country | Sample Size for STEM Teachers Survey | Sample Size for School Leaders Survey |
|---|---|---|
| Bangladesh | 989 | 622 |
| Cambodia | 1,050 | 450 |
| Kyrgyz Republic | 1,009 | 467 |
| Uzbekistan | 1,002 | 400 |

STEM = science, technology, engineering, and mathematics.
Source: Asian Development Bank.

Except for Bangladesh, stratified random sampling was not possible for the other three DMCs because of various constraints, and so convenience sampling was used in these countries. In the process, it was ensured that there is a good representation of rural and urban schools, teachers of different STEM subjects, and persons of appropriate age and gender profiles. For the survey on school leaders, a similar approach was used. As the number of survey items was lesser, it was necessary to reach out to fewer number of respondents—about 400 school leaders—to ensure psychometric validity.

The survey instruments were administered using a mix of approaches: online completion; eliciting of responses over mobile phone and keying in responses; and mailing of hard copies, depending on the DMC. In general, two approaches were used for each DMC.

Interviews were conducted either face-to-face or online by the respective national consultants.

The analyses were kept simple so that relevant parties can easily understand the findings. It was felt that it was not necessary to use advanced statistical approaches such as item response theory (Oon and Subramaniam 2013, 2018) or structural equation modeling (Caleon and Subramaniam 2014) to analyze the survey data.

The Likert scale data was keyed in by the research assistants, hired in each DMC for this study, into a specially prepared Excel file. Simple descriptive statistics were generated to get an overall picture of the findings.

To check for reliability of both surveys, Cronbach Alpha values (Cronbach 1970) were determined, both at the subscale level and at the overall instrument level.

For qualitative analyses of the open-ended questions, a simple coding scheme was used to classify responses into a few categories (Seoh, Subramaniam, and Hoh 2016; and Oon and Subramaniam 2010) that emerged naturally. For convenience, only the major strands of thought that appeared in the open-ended responses were used. For each category, a weighting was generated to indicate the preponderance of the responses with respect to the total number of responses obtained for each question. This gives some indication of the kind of views that were prevalent in the responses. The research assistants were briefed on how to do the coding and generate the weightings.

For analyses of interview data, the responses were parked into a few categories that emerged from the data.

**Desk work.** A review of educational documents that were made available for this study was also undertaken.

**Internet search.** A search of the web was undertaken to explore the presence of science centers and scientific societies in the country as well as their activity levels, where appropriate.

**Scholarly databases.** A search of scholarly databases of the major international science education journals, mathematics education journals, physics education journals, chemistry education journals, biology education journals, and STEM education journals was undertaken. The purpose was to explore the research activity levels of academic staff of teacher education institutes in each DMC. It is emphasized that the research output does not refer to content disciplines; for example, materials science, nuclear physics, and others. In other words, the focus is on educational research in the sciences, including mathematics.

There are countries whose education systems are highly regarded. While it would be good to compare the STEM education practices of the four DMCs with a number of other countries, it was restricted to a comparative evaluation mainly with Singapore and Finland, as their education systems are highly regarded, and have been widely written in the media.

**Survey of STEM teachers.** The reliability of the instrument and the subscales was assessed by evaluating a metric called Cronbach Alpha (Cronbach 1970). The usual rule of thumb for reliability is that Cronbach Alpha should be at least 0.70 (Nunnaly 1978). This metric was exceeded for most of the subscales as well as for the overall instrument in each of the DMCs (Table A1.2). That means the STEM teachers' survey instrument developed for this study shows high reliability, and that the findings can be endowed with significance and robustness. Irrespective of country, overall alpha values of the instrument, when sampled for each country, exceeds the recommended norm for Cronbach Alpha. In an instrument with a number of subscales, it is common for a few subscales to have values less than the recommended norm. This does not detract from the overall utility of the instrument.

The survey administered on teachers of STEM subjects generated a wealth of findings on the 12 subscales used in the instrument. The maximum rating possible for a statement is 5 on a Likert scale continuum (1–5). The mean rating for each statement, when referenced to the maximum possible rating, thus provides an indication of the strength of the assertion for each statement made by the respondents.

**School leaders' survey.** The reliability of the instrument and its subscales was assessed by evaluating a metric called Cronbach Alpha (Cronbach 1970). The usual rule of thumb for reliability is that Cronbach Alpha should be at least 0.70 (Nunnaly 1978) for an instrument. This was exceeded for most of the subscales and for the overall instrument (Table A1.3). The survey instrument thus shows high reliability. This indicates that the findings can be endowed with significance and robustness. For the survey in Uzbekistan, there were problems in gaining access to the Excel file in which the data was keyed in, and so what are indicated in Table A1.3 are estimated values. These estimated values are reasonable, based

**Table A1.2:** Reliability Values for Survey on STEM Subject Teachers' Views of STEM Education

| Subscale | Number of Question Items | Cronbach Alpha | | | |
|---|---|---|---|---|---|
| | | Bangladesh | Cambodia | Kyrgyz Republic | Uzbekistan |
| Syllabus in STEM teaching subject | 7 | 0.58 (0.67) | 0.84 | 0.71 | 0.84 |
| Assessment in your STEM subject | 6 | 0.64 (0.65) | 0.82 | 0.61 | 0.82 |
| Textbooks in STEM subject | 6 | 0.73 (0.87) | 0.87 | 0.70 | 0.87 |
| Your own preservice teacher training program | 5 | 0.91 (0.95) | 0.87 | 0.81 | 0.87 |
| ICT in STEM education | 9 | 0.86 (0.89) | 0.90 | 0.86 | 0.90 |
| Students' interest in STEM subjects | 5 | 0.78 (0.80) | 0.90 | 0.76 | 0.90 |
| Professional development programs in STEM education | 6 | 0.81 (0.82) | 0.90 | 0.78 | 0.90 |
| Pedagogy in STEM subjects | 8 | 0.73 (0.74) | 0.94 | 0.87 | 0.94 |
| Project work in STEM subjects | 5 | 0.76 (0.82) | 0.90 | 0.77 | 0.90 |
| Innovations in STEM education | 6 | 0.86 (0.87) | 0.89 | 0.80 | 0.89 |
| Laboratory | 6 | 0.73 (0.78) | 0.89 | 0.76 | 0.89 |
| Design and Technology workshop | 7 | 0.89 (0.93) | 0.93 | 0.80 | 0.93 |
| **Overall** | **76** | **0.96 (0.97)** | **0.98** | **0.94** | **0.98** |

ICT = information and communication technology; STEM = science, technology, engineering, and mathematics.
Note: Data for Bangladesh account for college teachers.
Source: Asian Development Bank.

**Table A1.3:** Reliability Values for Survey on School Leaders' Views of Education in their Country

| Subscale | Number of Question Items | Cronbach Alpha | | | |
|---|---|---|---|---|---|
| | | Bangladesh | Cambodia | Kyrgyz Republic | Uzbekistan |
| School leadership | 7 | 0.85 (0.83) | 0.69 | 0.43 | 0.70 |
| School improvement | 7 | 0.63 (0.69) | 0.33 | 0.48 | 0.70 |
| Relationship with national education authorities | 6 | 0.78 (0.76) | 0.81 | 0.75 | 0.70 |
| Relationships with other stakeholders | 6 | 0.72 (0.77) | 0.60 | 0.73 | 0.70 |
| Professional development of teachers | 6 | 0.81 (0.79) | 0.77 | 0.65 | 0.70 |
| **Overall** | **32** | **0.91 (0.92)** | **0.82** | **0.85** | **0.80** |

Note: Data for Bangladesh account for school head teachers (college principals). Data for Uzbekistan are estimated values.
Source: Asian Development Bank.

on a consideration of sample size, scale width, and distribution of responses across scale continuum. Of interest to note is that irrespective of country, overall alpha values of the instrument, when sampled for each country, exceeds the recommended value for Cronbach Alpha. In an instrument with a number of subscales, it is common for a few subscales to have values less than the recommended norm. This does not detract from the overall utility of the instrument. For example, in relation to the subscale on school improvement, the alpha values are less than the recommended norm for three of the DMCs, while in the other DMC it was at an acceptable value. This might indicate that this particular subscale may need a few more statements to remove further nuances in the construct of interest from respondents. This awaits further research.

## *Limitations*

For surveys, there were difficulties in getting stratified random samples of teachers of STEM subjects and school leaders respectively for three of the DMCs. However, as we were able to get a good sample size and representations for both groups, the findings can be endowed with significance.

There were difficulties in getting information and data for this study for most of the DMCs:

(i)   Syllabus for primary science, lower secondary science, physics, chemistry, biology and mathematics, and earth science, where applicable, as well as engineering and technology across the grade levels in schools. Needed are translated documents showing the various topics and learning objectives for each topic. Based on these, a matrix formed by the coordinate representations of knowledge dimensions versus cognitive processes (Anderson et al. 2001) for the topics can be constructed. This can be benchmarked against that for a developed country; for example, Singapore and Finland. Through these representations, we can see to what extent the subject syllabus is aligned with international best practices.

(ii)   Modes of assessment in schools; for example, formats of testing, the distribution of questions in tests on STEM subjects in leaving-level examinations according to Table of Specifications (Notar et al. 2004).

(iii)   Scheme of work, which shows how each subject is approached in school; for example, what topics are covered in each semester, how many hours are allocated for the subject.

(iv)   Status of laboratory facilities in the sciences. How equipped are these to support the needs of quality STEM education, how much time is allocated for practical work for each science subject per week, what types of practical work are conducted.

(v)   How is design and technology subject taught in schools. This is the nearest subject that integrates STEM in some way but not yet fully (Amir and Subramaniam 2012).

(vi)   National data related to outcomes in STEM education for graduating levels (commonly grades 6, 10, and 12); for example, student performance in the various subjects according to grade bands and gender.

(vii)   Extent to which STEM enrichment activities are provided for students in schools. These are important to pique student interest in science, improve attitudes toward science, and narrow gender gaps for females. The latter is also in relation to STEM-related nontraditional occupations, which are growing in demand.

(viii) To what extent are integrated STEM activities available for students and, if available, what are these? We have to note that the natural world is interdisciplinary in nature. However, science subjects are taught in schools separately as physics, chemistry, and biology—this is more for curricular convenience. It is important for students to get exposure in working on projects that are interdisciplinary in nature so that they can better understand the way the natural world works. More specifically, projects that integrate STEM would be helpful. There are two aspects to this: (a) adopting an integrated approach that merges the respective disciplines in STEM, which requires teachers to have in-depth knowledge of these disciplines and the associated pedagogy; and (b) promoting inquiry-based and experiential learning to improve soft skills (4Cs) as well as support for teachers to assess these.

# Education Technology

This four-country study aimed to produce a model for replicable country situation analysis of education technology (EdTech) readiness. The selection of four pilot countries was used to develop tools, processes, and procedures; and test such methods to develop a viable replicable and scalable model of national EdTech assessment. The tasks, based on mapping and analysis of the current situation on EdTech and the needs on using it in public education, specifically, in teaching and learning in schools, will help conceive appropriate, timely, and effective interventions at the country level.

## *Key Deliverables and Scope of Work*

This multicountry research project has resulted in the following five deliverables and outputs. To better understand each deliverable and task, the method used to accomplish the tasks and the resulting outputs of the tasks are given (Table A1.4).

### Table A1.4: Project Tasks, Methods, and Outputs

| Task | Method | Output |
|---|---|---|
| 1 Identify assessment framework to measure impacts of different education technology (EdTech) products and interventions in improving teaching, learning, and institutional management for K-12 education and skills development.[a] | Adopt/adapt and modify the Asian Development Bank (ADB) five-pillar framework that fits as a taxonomy/ lens in framing the understanding of the interdisciplinary nature of EdTech in a country. | Examined multiple frameworks and found the ADB five-pillar framework was a best fit, thus that framework and taxonomy was deployed and developed into five domains and 20 subdomains. |
| 2 Identify digital readiness assessment framework for the selected four developing member countries (DMCs) and, based on this experience, refine the assessment framework to identify digital readiness of other DMCs. | Design and develop original tools to assess country EdTech situation— utilization of primarily qualitative methods that will be carried out by the national consulting team. Focus on developing replicable and scalable tools. | Based on the framework adopted with five domains and 20 subdomains the project team developed in-depth research methods to explore and eventually explain issues, challenges, and gaps then presented as findings and recommendations in the country reports. |

**Table A1.4**    *continued*

| Task | Method | Output |
|---|---|---|
| 3  Prepare country-level reports on EdTech readiness in the selected DMCs, which should include:<br><br>(i)  mapping of the current situation of education policies to support EdTech solutions in the selected DMCs,<br><br>(ii)  mapping of the readiness of key institutions in implementing EdTech solutions and professional development programs to strengthen capacity for EdTech solutions,<br><br>(iii)  drafting policy framework to improve the capacity to implement EdTech solutions, and<br><br>(iv)  drafting country-level plans to implement EdTech solutions. | Each county will develop a country situation analysis that details the current state of EdTech along with issues, gaps, and findings based on evidence from the research and followed up with recommendations. | Four country reports derived from the aforementioned methods while addressing all major concerns of the deliverable have been presented. The result of each country-level report is a clear set of recommendations that will be used to further strategize and plan EdTech to ensure better investment and improved learning outcome. |
| 4  Provide best fit recommendations of EdTech solutions and preferred global and local partners in four selected countries. | The recommendation based on the five-pillar taxonomy will result in copious recommendations to the government, ADB and development partners. | Each country report resulted in about two findings per subdomain for a total of 40 findings with evidence. The findings are linked to suggestions for improvement then further refined into time-based recommendations. The recommendations were further synthesized to formulate high-level takeaways for the ministry of education of each respective country in addition to recommendations covering other entities in infrastructure and provider domains. |
| 5  Plan and support the organization of country-level workshops to seek feedback on the draft reports and organize learning events for selected practitioners and policy makers involved in K–12 education and skills development in the participating DMCs. | Present a summary of the findings in national workshops. | Completed workshop planning and preparation was submitted to ADB covering all four countries of the study. Both the national consultants and international consultant presented key findings based on national and international EdTech findings for the benefit of attendees, which included development partners, government, and others in the education community. |

<sup>a</sup>  K–12 refers to kinder through grade 12 education system. K–12 reform is not just about adding grades to upper secondary schools; it allows restructuring of other parts of the education system. https://www.adb.org/sites/default/files/publication/177761/transitions-k12-education.pdf.

Source: Asian Development Bank.

## *Country Situation Analysis Reports*

The main output of the project has been presented through country-level situation analysis outlining the EdTech condition or situation in each of the four countries. The reports are structured to follow the five pillars or domains.

(i)    **infrastructure**, including quality, coverage, and accessibility;

(ii)   **government:** legal environment of information and communication technology for education, government policy, planning, and activities;

(iii)  **schools and teachers** situations in schools, including systems, teachers' capacity and skills, digital content, and curriculum (subjects) quality, outcomes, and assessments;

(iv)   **parents and students** situations, including accessibility, inclusivity, and digital literacy of the learners; and

(v)    **providers:** the competitive landscape of providers, including systems, content, technological integration services, and innovative solutions that support EdTech-based learning.

## *Methodology*

To ground findings in international best practice, the research methodology was aligned to the following frameworks:

(i)    **digital principles**, for adherence to best practice on information and communication technology for development (ICT4D) deployment standards;[1]

(ii)   **International Society for Technology in Education standards** for teachers (educators) and students to ensure that the research is aligned with leading understanding on teaching and learning goals;[2]

(iii)  **Bloom's Taxonomy** of learning to position a cognitive framework; and

(iv)   **ADDIE** (analyze, design, develop, implement, and evaluate) instructional design framework to ensure logical flow.

The research methodology was applied to the EdTech five pillars (domains) assessment framework provided by the Asian Development Bank. Based on the five-pillar framework, a team of researchers representing each of four countries in the project developed a research framework and a question matrix mapping tool. Through this, 20 subdomains were identified that are related to the five domains (four subdomains per each domain). Each subdomain describes one key aspect of its respective domain. The subdomains were designed to describe the contextual situation regarding infrastructure, government, schools, teachers, students, and parents or providers and partners in the country.

Following the development of the question matrix mapping tool, a set of relevant methods have been identified, developed, and used to collect and analyze data. These included desktop research, qualitative interviews, and a teacher survey.

**Desktop Research—Literature Review.** The desktop research focused on reviewing relevant, publicly available reports, publications, and databases for a preliminary understanding of the situation. These

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1    Digital Principles (2020). https://digitalprinciples.org/principles/.

2    ISTE Standards. https://www.iste.org/standards/.

include reputable sources of information from international financial institutions, development agencies, nonprofit industry associations, and commercial organizations. The collected information and data were compared across sources to validate the accuracy of the sources. References to the literature are made throughout the report, including in the footnotes and the references sections.

**Qualitative—Key Informant Interviews.** In addition, a qualitative research methodology involving semi-structured qualitative interviews was designed with a focus on the key subdomains from the question matrix mapping tool. Because of the coronavirus disease (COVID-19) pandemic lockdown and mobility restrictions in place throughout the country, the interviews were mostly conducted over the phone. These targeted several key informant types: schoolteachers, school principals, students, parents, and key officials. Interview guides (semi-structured) intended for respective key informants were developed and tested initially on couple of teachers (and were refined further).

Because of the COVID-19 pandemic situation, country lockdowns, and quarantine, random sampling was not feasible. Therefore, "snowball sampling method" was used in most cases to obtain contacts. The snowball sampling method is a way to obtain as many contacts as possible by asking each respondent to provide several relevant contacts in their network. This process is continued until saturation point where responses received come to a point of saturation of knowledge on the issues of concern.

Purposeful sampling technique was used in conjunction with the snowball method to select key informants (interviewees).[3] The selection of this sampling method was to ensure to interview key informants across all regions of each of the project countries and with a spread across the domains.

Based on this sampling technique, the country targets for interviews followed and exceeded in most cases (Table A1.5).

**Table A1.5:** Key Informant Interview Mapping

| Domain | Infrastructure | Government | Schools /Teachers | Students /Parents | Providers |
|---|---|---|---|---|---|
| 1 | 1–2 national device providers | 1 government official on ICT policy | 10 school leaders | 20 students | 3 leading development partners |
| 2 | 1 telecom | 1 government official on education management information system | 20 teachers | 10 parents | 3 e-learning providers |
| 3 | 1 electricity provider | 1–2 preservice teacher training college | | focus group family | 2 digital content developers |
| 4 | | | | community leaders | |

ICT = information and communication technology.
Source: Asian Development Bank.

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[3]    Done mainly to gain proper spread across a host of demographic features
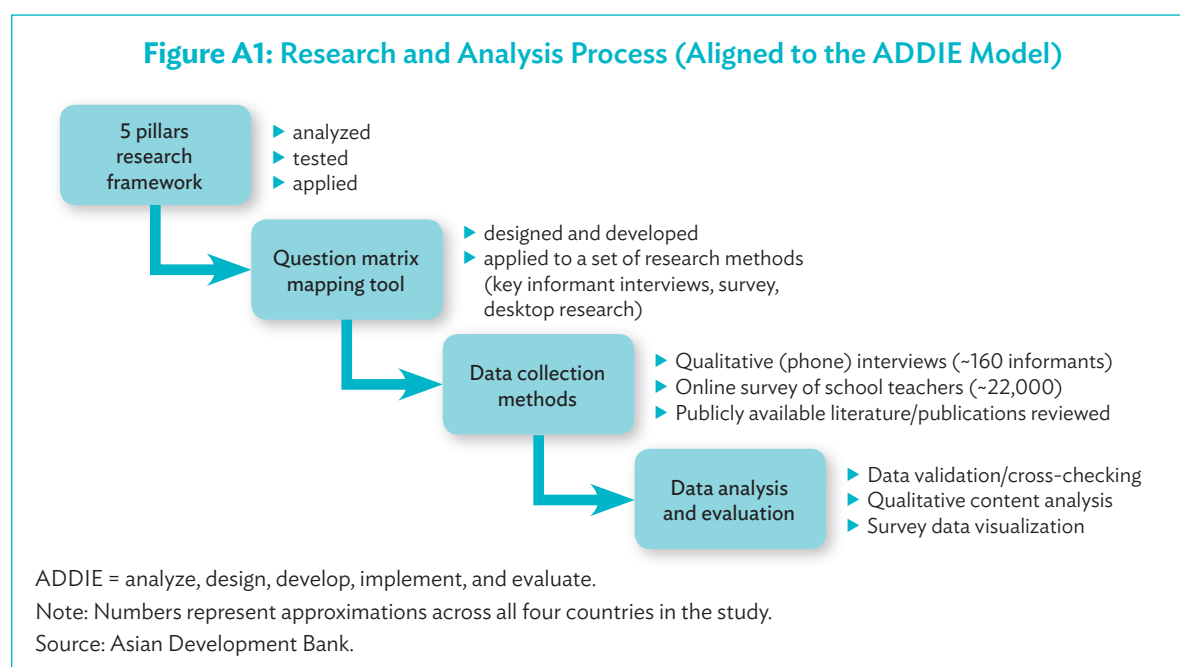
The interviews were recorded using apps on smartphones, and notes were taken so that the researchers could review later. Written or verbal consent was taken prior to each of the interviews.

Once the data were collected, sorted, summarized, and synthesized to draw conclusions, reveal key themes to present in the summary.

**Online teacher survey.** An online teacher survey was developed, tested, and deployed using social media channels (online) in each country the minimum response was ~1,200 with a maximum of ~14,000. Each country targeted the minimum 370 valid and demographically properly spread responses, which would result in a significant error of 5%. In reality, each country then produced returns well above and beyond statistically significant in the 5% error rate covering demographics, including breakdown based on region of the country, urban–rural spread, school size, gender, and subjects taught. Thus, the survey was fully statistically significant on all accords.

The survey responses were collected using an online survey designed with KoboToolBox.[4] The survey itself was distributed via posting the survey announcement and the survey link in a group channel (Telegram, WhatsApp, and Facebook). These social media groups and channels were meticulously explored and selected to facilitate reaching out to the targeted respondents (schoolteachers) in a fast and efficient method as possible. In all four countries, results were met or exceeded within 1 week.

Subsequently, the KoboToolBox survey responses were downloaded onto an Excel spreadsheet for validation and error cleaning, formatting, and visualization of the results. The main findings of the survey have been incorporated into country situation analysis findings through evidence support, and thus helped to build suggestions and recommendations.



**Figure A1: Research and Analysis Process (Aligned to the ADDIE Model)**

5 pillars research framework
▶ analyzed
▶ tested
▶ applied

Question matrix mapping tool
▶ designed and developed
▶ applied to a set of research methods (key informant interviews, survey, desktop research)

Data collection methods
▶ Qualitative (phone) interviews (~160 informants)
▶ Online survey of school teachers (~22,000)
▶ Publicly available literature/publications reviewed

Data analysis and evaluation
▶ Data validation/cross-checking
▶ Qualitative content analysis
▶ Survey data visualization

ADDIE = analyze, design, develop, implement, and evaluate.
Note: Numbers represent approximations across all four countries in the study.
Source: Asian Development Bank.

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4    KoboToolBox. https://kobo.humanitarianresponse.info/.

### *Research Paradigm*

The requirements for mapping the situation related to EdTech in each country do not require interviewing large numbers of respondents. Instead, understanding is derived through a qualitative process where repeated discussion result in saturation of understanding. The methodology will be mostly based on qualitative research framework with key informants with the focus being on the credibility and expertise or professional background of such respondents.

It is proposed that a digital literacy assessment of teachers and students, mini directed surveys may be developed through a quantitative research modality.

### *Question Matrix—Mapping Tool*

The central element of the research work will be implemented via a question matrix mapping tool. The tool will be used to define the five domains (pillars) related to EdTech situation in the country. Within the five domains, key areas or subdomains will be identified. For each of the subdomain, a set of mapping questions will be developed, tested, and used in key informant interviews and in possible mini surveys with relevant respondents across all the five domains (pillars).

Each of the key questions in the question matrix mapping tool would be developed further in terms of exploring other aspects when data comes in.

One of the potential outputs of the tool may be a set of parameters for an EdTech readiness index, which could be numerical representation showing status and longitudinal change in countries EdTech readiness. Although this line of work may be beyond the scope of this assignment, a visualization demo can be developed along with proposed parameters (based on the five pillars framework and the question matrix mapping tool).

### *Assessment Framework*

Work was done to identify an assessment framework based on the five-pillar taxonomy provided by the Asian Development Bank. The assessment framework consisted of 30–50 key informant interviews (variable depending on the country) based on the below expanded taxonomy. To strengthen the understanding of teacher digital access, skills, and literacy, a survey's purpose was to add data to that aspect of the assessment framework.

## Table A1.6: Domain and Subdomain Assessment Framework Mapping

| Key areas | Infrastructure | Stories | Government | Stories | Schools/Teachers | Stories | Students/Parents | Stories | Providers | Stories |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | IF1 (telephony, internet connectivity, user stats) | Story about telecommunication access and internet connectivity—issues, challenges, availability, etc. | GO1 (policy/funding) | Story about ICT related policies, plans and funding at the national level—implementation, limitations, challenges, etc. | ST1 (teacher capacity in EdTech) | Story about teachers' digital literacy and the description of training support provided to teachers in improving their digital literacy skills at the school level (gaps/issues). | SP1 (digital literacy of students) | Story about students' digital literacy and the support they receive from parents/guardians (issues/gaps). | PR1 (e-learning systems) | Story about types of e-learning management systems and educational apps: users, costs, use cases, limitations (compatibility, accessibility). |
| 2 | IF2 (devices and hardware) | Story about the national level availability of ICT devices that are related to EdTech—availability, costs, maintenance, providers. | GO2 (curriculum and content) | Story about the state of integration of EdTech in the national curriculum to support learning outcomes (limitations and gaps). | ST2 (equipment and software) | Story about types of technology support provided by school to admin staff, teachers and students (issues/challenges/concerns/gaps). | SP2 (connectivity and devices at home) | Story about students access to devices and internet connection and the support they receive from parents/guardians (issues/gaps). | PR2 (online content) | Story about available digital content, sources and language, upload/storage methods, distribution, limitations. |
| 3 | IF3 (power, electricity access) | Story about the national electricity infrastructure and issues/challenges that schools and learners may have regarding access to electricity. | GO3 (education performance measurement) | Story about ICT used to collect and analyze key system performance data (systems, processes, issues, challenges, gaps). | ST3 (governance) | Story about the policies, budget and monitoring process and/or tools (differences/gaps across schools). | SP3 (online access to curriculum content) | Story about availability and types content that assists students in reaching learning outcomes (as outlined in the national curriculum). | PR3 (integrators, emerging tech) | Story about system integrators, existing technologies that support e-learning (email, communication apps, social media), and emerging technologies (AI, AR/VR). |
| 4 | IF4 (TV/radio broadcasting) | Story about broadcasting methods, content creation and transmission, how it supports curriculum delivery and attainment of learning outcomes. | GO4 (training) | Story about ICT pedagogy integration in preservice teacher education. | ST4 (community outreach) | Story about how schools/teachers use ICT to communicate with parents/students/community: tools they use, issues they discuss (differences/gaps). | SP4 (community support) | Story about how local community supports students with access to devices, internet, e-learning content and technical support (challenges, gaps). | PR4 (partners, sponsors) | Story about partners and sponsors on EdTech: administrators, sponsors, funders, projects supported and/or funded, project locations. |

AI = artificial intelligence, AR = artificial reality, F = infrastructure, GO = government, ICT = information and communication technology, ST = schools/teachers, SP = students/parents, P = providers, VR = virtual reality.

Note: Domains are listed in blue text, stories refer to a description of each subdomain.

Source: Asian Development Bank.

# SYNOPSIS STATEMENTS

### Table A2.1: Synopsis Statements on National Infrastructure

| Theme | Synopsis on National Infrastructure |
|---|---|
| Connectivity | Internet access must become national right—focus on broadband speed internet for all should be a cornerstone of national development, education, and prosperity. |
| Devices | Both tax incentives and low interest loans should be used to encourage increased purchase and uptake of household-owned computers. |
| Telecom/broadcasting | Conduct in-depth analysis of national capacity in broadcast TV/radio and social media to facilitate increased educational opportunity (to create a learning society). |
| Electricity | Recognizing that digital economy is completely dependent on sources of electricity, government must prioritize electrification and seek alternative delivery modalities to continually decrease cost, while improving on quality. |

Source: Asian Development Bank.

### Table A2.2: Synopsis Statements on National Education Technology Providers

| Theme | Synopsis on EdTech Providers |
|---|---|
| e-learning systems | Government must work closely to advocate the development of a vibrant e-learning industry that excels in addressing national digital platform and application priorities. |
| Online content | In recognition of a lack of clear standards on quality and locally available content, the government must develop guidelines and promote advocacy with content providers to ensure that accessibility ideals are met. |
| Emerging tech | Cutting edge education technology as a driver of innovation must be recognized and supported. |
| Partnership | Recognizing that government cannot obtain education technology goals in isolation, a robust partnership plan that nurtures and encourages direct participation in reaching shared education goals should be designed, developed, and encouraged. |

Source: Asian Development Bank.

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## STEM and Education Technology in Bangladesh, Cambodia, the Kyrgyz Republic, and Uzbekistan
*A Synthesis Report*

This publication focuses on the state of science, technology, engineering, and mathematics (STEM) education and education technology (EdTech) in Bangladesh, Cambodia, the Kyrgyz Republic, and Uzbekistan. The studies conducted from May 2020 to May 2021 include situation analysis reports on STEM education and EdTech for each country in the general education subsectors (primary and secondary). The publication covers discussions of the findings from the studies, identifies gaps and potential intervention areas in the four developing member countries (DMCs), and provides policy recommendations that can also be referenced for other DMCs of the Asian Development Bank.

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