Japan International Cooperation Agency

Strategic Policy for National Science, Technology and Mathematics Education

Main Document

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Abbreviations and Acronyms

AAU	Addis Ababa University
CRGE	Climate Resilient Green Economy
CSMASEE	Centre for Strengthening of Mathematics and Science Education in Ethiopia
COC	Center of Competence
CPD	Continuing Professional Development
CTE	College of Teacher Education
EBC	Ethiopian Broadcasting Company
ESDP	Education Sector Development Program
FDRE	Federal Democratic Republic of Ethiopia
FGD	Focus Group Discussion
GEQIP	General Education Quality Improvement Program
GTP	Growth and Transformation Plan
ICT	Information and Communication Technology
InSET	In-Service Education and Training
IPET	Initial Professional Education for Teachers
IOP	Institute of Physics
JICA	Japan International Development Agency
KII	Key Informant Interview
MEXT	Ministry of Education, Culture, Sports, Science and Technology (Japan)
MLC	Minimum Learning Competency
MoE	Ministry of Education
MoST	Ministry of Science and Technology
MSIC	Mathematics and Science Improvement Centre
MST	Mathematics, Science and Technology (Japan)
NLA	National Learning Assessment
NSF	National Science Foundation (USA)
PISA	Programme for International Student Assessment
PTAs	Parent – Teacher Associations
R&D	Research and Development
SMASEE	Strengthening Mathematics and Science Education in Ethiopia
STM	Science, Technology and Mathematics
STEM	Science, Technology, Engineering and Mathematics
STME	Science, Technology and Mathematics Education
TIMSS	Trends in International Mathematics and Science Study
TVET	Technical Vocational Education and Training

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1. INTRODUCTION

Science, technology and mathematics (STM) are critical to and supportive of the quality of education being offered today, from the adoption of common internationally benchmarked standards (international student assessment surveys) to better teacher preparation and enhanced coordination across the entire education system. In fact, STM is a focus area for the Ethiopian Government for the national education system and a manifestation of the country's overall development endeavour. The government stresses a multidisciplinary approach for better preparing students in STM subjects and increasing the quantity and quality of post-secondary graduates prepared for STM occupations.

The Ethiopian Government’s motivation for this new emphasis on STM education (STME) is justified for a number of reasons. Increasing the number of students versed in STM and promoting sufficient and qualified graduates ready to pursue STM careers or advanced studies is critical to the country's rapidly growing economy. A labour force that is not equipped with the right skills in STM fields cannot accommodate the current demand for such skills, and will fail to meet the needs of Ethiopia’s (potentially) increasing manufacturing industry and construction market.

Therefore, politicians, education leaders and policymakers at all levels have called for a new emphasis on STME in the nation’s schools, from primary school through to post-secondary education. STME is a means of developing a citizenry capable of scientific thinking and logical reasoning, in order to form cohesive social integration across all fields of the endeavour of nation building. Sufficient literacy and numeracy, as well as the process skills of science backed up with proper technological knowledge, are expected to help scale up the level of thinking and build up a literate citizenry who will be committed to nation building and national development. In this respect, there is a strong consensus among key actors that the country needs to have a national strategic policy for STME, which is a means for achieving these ambitious goals.

This background document for a national strategic policy for STME has been developed for this reason, looking at pre-school through to tertiary levels of education. This strategic policy foundational study provides support for the strategic policy to directly link and contribute to the objectives stated in the second Growth and Transformation Plan (GTP-II), the fifth Education Sector Development Program (ESDP-V) and Climate Resilient Green Economy (CRGE). It can be further adopted in the form of a strategy and action plan at the regional and zonal levels. It guides the education sector on how to develop the human resources required to achieve the national objectives of leading the country's rapid and demanding economic growth trajectory.

The terms ‘policy’, ‘strategic policy’ and ‘strategy’ in this document refer to a standalone course of action taken by a national government intended exclusively to influence and determine strategic decisions, actions, plans and other matters in a particular field; in this case, by the Ethiopian Government regarding STME, in order to develop an ethical and committed citizenry with a sound knowledge base of critical thinking and reflective inquiry, and endowed with proper scientific process thinking skills.

This strategic policy was prepared taking into account the voices of various stakeholders, including school teachers and administrators; education officials with curriculum development and implementation expertise; science and mathematics education experts from the Ministry of Education (MoE) and regional education bureaus; and parents and students. Moreover, professional associations and stakeholders were consulted for the development of this strategic policy document. In addition, relevant key national and international documents were studied in framing this document. These were:

a) Science Education Policy-Making; Eleven Emerging Issues (Fensham/UNESCO, 2008).
b) Mapping Science Education Policy in Developing Countries (Lewin/World Bank, 2000).
c) Science Education in Europe: National Policies, Practices and Research (EACEA/EU, 2011).
d) Various studies illustrating the different global experiences in improving science education.

While developing this strategic policy background document, the working team also held consultation meetings and discussions, both amongst themselves and with concerned officials and experts in the MoE, the Japan International Development Agency (JICA) as well as with other stakeholders. The first draft of this document was shared with various stakeholders for feedback and essential amendments, namely: directorates at the MoE (Curriculum Development and Implementation; General Education Inspection Directorate; Special Needs and Inclusive Education; Teachers and Education Leaders Development Directorate; Education Sector Reform Directorate; Communication Affairs Directorate; the Centre for Strengthening Mathematics and Science Education in Ethiopia (CSMASEE); the Ministry of Science and Technology (MoST); and finally mathematics and science experts/lecturers at Haromaya University, Dire Dawa University, Kotobe University College, Addis Ababa University and Jima University.

Ministers, regional education bureau staff and regional education leaders can use this guide to further the implementation of STME agendas and direct practical courses of action that will enhance the quality of STME at all levels of the education system. By placing an emphasis on STME, this does not mean that the education system needs to be completely revised; rather, it reinforces efforts already underway, for example towards meeting the targeted 70:30 professional mix in higher education (70% of students enrolled in science and technology and 30% in social sciences), and to getting primary and secondary education, including technical and vocational education and training (TVET), on track to feed into this aim. The strategic policy will aim to strengthen the organization and delivery of STME in both primary and secondary education to ensure development, and in addition facilitate the way for the 70:30 professional mix. It will also reinforce the implementation of strategic interventions that are critical and useful for meeting the nation's needs.

1.1. DEFINITION AND SCOPE OF STME

STME is a central preoccupation of policymakers across the world. In many countries, discussions about STME are advanced in terms of claims about shortages of highly skilled labour.[1] Policies with a strong focus on STM skills have been put in place in most countries of the world with the formation of ministries of science and technology and/or ministries of education.[2] Such policies place emphasis on developing human resources in the high-tech knowledge economy throughout preschool, primary, secondary and tertiary education. Indeed, introducing STME from the basic educational levels onwards helps to form a strong and early foundation for STME that can be built upon in higher levels.

In this strategic policy background paper, STME refers to teaching and learning in the fields of science, technology, and mathematics. It includes educational activities across all grade levels— from pre-school to tertiary—in both formal (e.g. classrooms) and informal (e.g. after school programs) settings. Ethiopian federal policymakers and implementers have an active and enduring interest in STME and the topic is frequently raised within the MoE, MoST, as well as at mathematics, science and technology universities and institutions dealing with policy and academic debates.

STM are distinct and complementary approaches to knowledge and practice that have been proven to produce benefits for society. Mathematics and the disciplines within the natural and physical sciences contribute broadly to all disciplines and practices used for the betterment of society. Mathematics aims to understand the world by performing symbolic reasoning and computation on abstract structures. It discloses relationships among these structures and captures certain features of the world through the processes of modelling, formal reasoning and computation. Mathematics contributes to biology, medicine, social sciences, business management, advanced design, climate studies, finance, advanced materials and many more.

For the purposes of this strategy, the scope of science in STME is limited to the enabling disciplines within the natural and physical sciences and mathematics, though this also lays a proper foundation for other disciplines. The natural and physical sciences and mathematics encompass: mathematical sciences; physical sciences such as physics, earth science, etc; natural sciences encompassing chemical, biological and biomedical sciences; information, computing and communication sciences; and technological sciences, business and finance demanding mathematical foundations such as optimization and operations research; and many more within each distinct subject. These sciences rely on causal relationships, characterized by systematic observation, critical experimentation, hypothesis formation, justification or falsification, modelling, etc., which all require backing through scientific thinking, scientific process skills, the application of mathematics and the support of technology.

Technology provides goods and services to satisfy real-world needs. Building on the growing importance of information and communication technology (ICT), such as those enabled by the Internet, technology increasingly encompasses the cross-section of knowledge and skills that drive the advancement of the business, government and non-government service sectors – the so-called service sciences.

Owing to the needs and justifications for the development of the STME strategic policy, an assessment was made to explore global experiences from which useful and compatible lessons could be extracted. The following section addresses the global discourses and experiences of countries whose experiences could be useful for this purpose, including those that either share a similar context to Ethiopia, or which were previously in a similar situation but experienced rapid growth.

1.2. GLOBAL DISCOURSES ON AND EXPERIENCES OF STME

1.2.1. Background

Experiences from developed countries and emerging economies underscore that increasing the number of high school, college and postgraduate students majoring in STME subjects is critical for sustainable economic development. It is not uncommon to see most STME graduates go into STME jobs and occupations that are among the highest paid and fastest growing. Moreover, at the global level, individuals with STME degrees who enter STME careers experience lower unemployment rates compared to workers who enter other fields, which means that STME workers enjoy greater job security. In other cases, students who study STME are able to enter a variety of fields and earn a salary premium, even when they pursue non-STME occupations. In turn, STME education boosts countries' competitive edge and innovative capacity, both of which sustain economic growth.[3]

To support Ethiopia's rapidly growing economy, this requires advanced preparation to meet the demands of the growing number and diversity of industries through the provision of STME graduates who will be fit for the market, who will be employable and can make valuable contributions in their fields, and who can enhance their self-employability and assure creativity, innovation and the advancement of knowledge.

Many countries carry out international student assessment surveys under agreed conceptual and methodological frameworks with a view to providing policy-oriented indicators. The relative standing of countries' average test scores is the indicator that attracts the most public attention. Since the 1960s, a country's relative score has become an important influence on national education policies, generating pressure to borrow educational practices from top-performing countries[4] and to review one's own practices based on the study reports.

Globally, student achievement in science is assessed by two large-scale international surveys, namely TIMSS and PISA. TIMSS (Trends in International Mathematics and Science Study) measures the mathematics and science performance of fourth grade and eighth grade students.[5] PISA (Programme for International Student Assessment) measures the knowledge and skills of 15-year-old students in reading, mathematics and science. These two surveys focus on different features of student learning. Generally speaking, TIMSS aims to assess 'what students know', while PISA seeks to find out 'what students can do with their knowledge'. In these regards, Ethiopia seeks to measure both what students know and what they can do with their knowledge.

TIMSS uses the curriculum as the major organizing concept. The data collected has three aspects: the intended curriculum as defined by countries or education systems; the implemented curriculum actually taught by teachers; and the achieved curriculum or what students have learned.

Prior government commitment is essential and a building block in terms of forwarding STM in any country. To learn from other countries' experiences, five countries have been selected and their cases are presented below. Some of the criteria for selecting them included:

a) Similar background (large population, showing relatively fast growth in science and technology);
b) Availability of STM(E) strategies and guidelines;
c) The main objectives and pillars of their STME strategies and guidelines;
d) Key achievements in terms of translating strategies and guidelines into practice, as justified by TIMSS and PISA;
e) Geographic diversity (Middle East, Asia, Africa).

Some of the selected countries discussed achieved successful economic and social development mainly due to the fact of having both an export-based market economy and a citizenry committed to nation building, and who are supported by efficient and effective STME in schools founded on the accumulation of strong technological capabilities. Again, the countries' performances on the science and mathematics scales are commendable.

From our literature review, it was extremely difficult to find a country with an explicit 'science and/or mathematics education policy'. Most countries have either a 'science and technology policy' or a general 'education policy'. Ethiopia could be a pioneer country in setting and implementing a fully-fledged and standalone 'STME strategic policy'.

The following countries were selected in order to review their relevant experiences in STM and their STME strategies, plans and frameworks. The lessons learnt from these countries were drawn to suit the Ethiopian context.

A. CHINA: More than three decades ago, China's reform leader, Deng Xiaoping, began economic reforms that would transform the world in the 21st century, as China emerged as a global economic superpower. The centrepiece of the strategy was science and technology, which Deng believed would be the means to transform the then poor agricultural country into an affluent nation. As a result, China is now the second-largest economy in the world after the United States. Moreover, time would seem to be on China's side. While American students are slipping in the world rankings for science and mathematics, China's students are rising.

According to US National Science Foundation (NSF) data, China has one of the highest rates of science, technology, engineering and mathematics (STEM) to non-STEM degree production in the world. The international average for the ratio of STEM to non-STEM degrees was 26.4% in 2002. China stood second in the world in the proportion of STEM degrees awarded with 52.1%, next to Japan with 64.0%. On the other hand, the US ranks near the bottom in the proportion of STEM degrees with 16.8%, although it ranks third (behind Japan and China) in the absolute number of STEM degrees awarded. Science is still popular among students in China, while it attracts only a tiny fraction of young US graduates.

Deng Xiaoping's early vision was for the transformation of an agricultural-based society into an industrial society, with the support of science and technology. Today, the goal is to transform China from an industrial society into an innovative society. One way that the government plans to achieve this is to greatly increase the level of investment in research and development (R&D), with the target of R&D contributing 2.5% of GDP by 2020.

R&D in China has already grown more than tenfold in ten years, from around US$12 billion in 2001 to about $135 billion (Bt4 trillion) in 2011, while investment in basic science and applied research has increased more than six-fold. Such investment should help attract Chinese science graduates from foreign universities to return home, where they will be able to work on research initiatives in science. Moreover, the government is also offering strong inducements for Chinese experts living overseas to return to China under its 'One Thousand Talents' program.

Science and technology continue to be of critical importance to the Chinese economy. With the rapid development of both society and the economy in the People's Republic of China, the importance of technology education has been gradually recognized by both the government and the people of China. China has benefited in many areas, including in science and technology, since China opened its doors to industrialized western countries.

Historically, from 1902, when the People's Republic of China was established, until 1949, the foundation of technical and vocational education was very weak (UNESCO, 1985). Ever since 1949, technical and vocational education in China has gone through a continuous process of reforms, readjustment and improvement. “Technology is the productive force” is a well-known slogan in China that is frequently cited. The Central Committee of the Communist Party of China declared: “A vital factor for the success of our cause lies in the availability of skilled people, which requires the vigorous development of education as economic growth allows”.

Technology education, which involves the study of communication, transportation, construction and manufacturing systems as currently implemented in the US and some other advanced countries, has not yet been established on mainland China. A technology teacher education major does not exist at the university level. Technology education in China exists solely in the forms of science and engineering education in the universities. In some elementary and secondary schools, technology education is currently included in vocational and technical education or integrated with general science education.

B. ISRAEL: Abell (2002) describes that at the beginning of the 1990s, a national committee, The High Committee for Science and Technology Education, was formed to examine the state of science education in Israel. The result of the committee’s work was Harary’s 1992 report ‘Tomorrow 98’, which has since guided the basic principles of science education in Israel. The essence of its suggestions is that:

> Science and Technology education is the core of scientific infrastructure. (…) The government of Israel will announce a national curriculum to strengthen, deepen and improve the learning (…)preparing the next generation of citizens for life in the techno-scientific age. Implementation of this policy includes an interdisciplinary approach to the subject (…) science and technology in our time are inter-linked and overlap in a variety of surprising ways (…) the learning of science and technology must be combined.

The Ministry of Science, Technology and Space in Israel has been given the mandate to advance, encourage and foster science to the highest levels of achievement and creativity and to position Israel as a leading scientific and technological power.

The ministry identifies scientific and technological research areas that are of national priority. In addition, it acts to develop human capital, increase the social and economic vigour of Israeli society, and maintain equal opportunity in all areas of science and technology.

Among its goals, the ministry constitutes a connecting link between basic research, applied research and industrial development. Another central goal of the ministry is to strengthen as well as initiate international scientific collaborations with other countries and international organizations.

Since its establishment, the state of Israel has continually invested in the nurturing of science, technology and higher education. To a great extent, the country's economic achievements rest on Israel's ability to tap into its available scientific and technological potential. Israel's scientific research greatly contributes to establishing its international status and geopolitical position in the area, provides the country with a respected place among the developed countries of the world, and acts as leverage for economic growth.

In recent years, another principal objective of the Ministry of Science and Technology has been to bring the general public, particularly those on the periphery of Israel as well as younger generations, closer to science by promoting science approachability. This has resulted in the establishment of Regional Research and Development Centres in the north, in Judaea, in the Negev desert and at the Dead Sea. These centres are engaged in research that is grounded in local challenges. They attract researchers, offer employment opportunities and contribute to local development. The Regional Research and Development Centres are unique initiatives that serve as a basis for scientific excellence in peripheral areas and are an exemplary model in the global community.

Scientific and technological research forms the basis for constant economic growth and positions Israel globally as a technologically advanced country and a leader in science and research.

The education policy of Israel has the following objectives:

- To strengthen science and technology education in K-12 classes by developing new curricula, teaching aids and teacher retraining, thus providing an understanding of science and technology to all students.
- To ensure equal opportunity for science education among all sectors of Israeli society.
- To increase support to academic institutions to allow for increased numbers of students in science and engineering subjects.
- To introduce modern computer and internet communication facilities into the public school system.

C. JAPAN: Japan is not well endowed with natural resources but did nevertheless successfully achieve economic prosperity in a relatively short period coming out of the rubble of the Second World War. Japan aims to be a nation based on the creative use of science and technology, and the main goals of mathematics, science and technology (MST) education are to maintain a high standard of knowledge across the population and develop creativity. Continuing reform of MST education at the elementary and secondary school levels is therefore vitally important.

Some key decisions that Japan has taken in this regard are:

A) The government adopted policy initiatives that aligned education, especially in science and engineering, with the development of science and technology and highly efficient human resources (IIC-JICA, 2007).
B) Apart from the policy initiatives that have contributed to improving MST education at the national level, Japan has an unbroken tradition of continuous efforts by teachers to improve their lessons at the grassroots level since the Meiji Era (1868-1912). In an effort to give lessons that are understandable to students, teachers try to associate "school knowledge (teaching content)" with "everyday knowledge (wisdom for everyday living)".
C) Textbooks in Japan are concise, inclusive and systematic. Since they are built on what is already learned, they are highly evaluated in terms of learning continuity. Likewise, guidebooks for teachers in Japan are user-friendly. They include information not only on questions, answers and explanations for how to solve the questions, but also on how to organize lessons and the content knowledge necessary for teachers to deliver the lessons.

Surveys reveal that the achievement of Japanese students in both science and mathematics is high by world standards. International comparisons suggest three reasons for this high level of STME in Japan:

1) High national academic standards embodied in the Course of Study (see below).
2) A legal framework that provides free textbooks during compulsory education and central government financial support for equipment used in science, mathematics and technology.
3) Lesson study (self-initiated ongoing study) conducted by teachers.

The Course of Study for Lower Secondary Schools – a set of official curriculum guidelines from the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan – defines the overall objectives of science subjects, for instance, as "to develop attitudes and abilities to investigate scientifically, to foster scientific views and thinking, and to deepen the understanding of natural phenomena through enhancing students' interest in nature and letting them engage in observations and experiments with a clear purpose". In other words, the goal is to help students develop four kinds of abilities and attitudes as follows:

1) Scientific methods:
   - Acquiring new knowledge based on facts gained by observation and experiments.
   - Sorting out and organizing knowledge in a systematic way that already exists and/or that is not yet fully organized.
2) Scientific attitudes:
   - An attitude of observing things properly and objectively.

- An attitude of identifying relationships between things and even establishing laws for them by sharpening one's intellect and senses.
- An attitude of being cautious, scrupulous and thorough in doing things.
- An attitude of always having questions in mind.

3) Scientific perspectives:
    - Science provides students with a foundation for viewing nature, or a particular way of perceiving nature. A view of nature encompasses a view of matter, life and the universe.
4) Scientific thinking:
    - Scientific thinking refers to a process of establishing scientific knowledge by dividing problems/phenomena into smaller parts, organizing and systematizing the facts and findings interrelated by a particular principle, and identifying common rules behind facts and findings collected about a phenomenon. It takes the form of analytical, synthetic, inductive, deductive and analogical thinking.

D. KENYA: The Ministry of Education, Science and Technology, National Education Sector Plan (2015) of Kenya states that the nation's education policies emphasize the importance of literacy and numeracy (MoEST, Kenya 2015). Ensuring that every Kenyan pupil is able to read, write and do basic mathematics by the end of Grade 3 provides the essential foundation for successful future learning and for making a contribution to Kenya's social and economic vision set out in the Kenya Vision 2030. This document identifies science, technology and innovation as a necessary foundation for the country's social and economic development. The national development blueprint recognizes the role of science and technology in development, as new knowledge is expected to boost wealth creation, social welfare and international competitiveness.

With increased unemployment and the need to provide skills that will enable youths to be self-employed and competitive in the global job market, there has been an increased sense of urgency to promote science as the avenue through which self-sustaining skills can be imparted. As a result, the government, with the support of other stakeholders, has increasingly given priority to the construction of science laboratories and science rooms, and the provision of laboratory equipment and science kits, mainly in public secondary schools. Kenya has already recognized and is taking steps towards purchasing and installing laboratory equipment, apparatus and science kits; tools that facilitate the effective teaching of science and other skills-oriented subjects. Improvement of infrastructure, including computer laboratories and the installation of electricity lines or solar power in all primary schools in phases, will make it possible to implement the vision of better science and mathematics education.

As a result, the performance of sciences in secondary schools has been improving since the introduction of laboratory equipment grants in 2003 in secondary schools and the introduction of the Strengthening of Mathematics and Science Education (SMASE) initiative. Part of the effort includes collaborating with strategic partners, the private sector and NGOs in the provision of infrastructure, including laboratories and laboratory equipment and facilities such as laptops for Standard One pupils, as articulated in the Jubilee Manifesto.

According to Oduol (2006), as an organization the Kenyan Ministry of Education, Science and Technology has a rich and varied database, encompassing data from the Kenya National Examination Council, Teachers Service Commission, and the Kenya Institute of Education, among others. This database can be used to monitor and evaluate education processes, and the results can be used effectively for the management of the primary school sector in Kenya, at the school, district and national levels. Research shows that knowledge in mathematics and reading is basic to education and, given the centrality of mathematics and reading in a global context, therefore there is a need for policies that integrate all of the resources available in the country rather than maintaining separate efforts that are enhanced by a departmental approach to issues.

Oduol adds that some of these policies should include expected outcomes, which involve: a) enhancing the tuition currently provided in the school program; b) establishing incentives for school attendance, and monitoring attendance data at classroom, school, district and system levels; and c) ensuring that students have a place to write, which involves providing desks and chairs for all students in a school. There are also three important resource-related issues where policy is needed: a) class size; b) a regular place in the classroom for each child to sit and work; and c) meals provided at school.

Despite the policy and resource challenges, science education in Kenya begins in preschool in the form of a diffuse, amorphous introduction of simple scientific concepts through informal but guided activities. The role of the teacher at this stage is to provide the facilities and an environment that promotes informal exploration and experimentation during class activities. Although no formal, organized and structured science is taught, activities and opportunities to play, explore and experiment are made available and help introduce the learners (three-, four- and five-year-old children) to concepts that can be appropriately termed “pre-science”.

At the primary school level, the teaching of the scientific concepts introduced during preschool education is further explored in a less formal setting. The concepts are organized and presented as units. The lower primary represents a progressive transition from preschool “pre-science” to a more detailed and relatively advanced treatment of the topics in upper primary. As the topics become more detailed in upper primary, the student is given an indication of the discipline-based structure of the secondary school. Then the secondary school structure introduces four years of biology, chemistry and physics in addition to the mathematics that they have already been familiarized to.

Given the emphasis laid on science, technology and mathematics, the Kenyan government, apart from establishing the centre for SMASE, also launched in 2008 a

Science, Technology and Innovation Policy and Strategy focusing on areas of significant potential that have been identified under Vision 2030; science, technology and innovation will play a fundamental role in achieving the targeted benefits of the long-term plan. The National Science, Technology and Innovation Policy and Strategy proposes integrating science, technology and innovation into the eight identified sectors by ensuring that the sector players have access to the necessary technologies that will be relevant to the improvement of a diverse range of products, processes and services (Ministry of Education, Science and Technology-Kenya, 2008).

E. VIETNAM: Writing about the publication of the largest ever global school rankings, in May 2015 Sean Coughlan indicated that Vietnam had overtaken the US. Despite being a poor country, Vietnam has made significant achievements in increasing the value of its gross national product, raising its export turnover, controlling the population growth rate, raising living standards and reducing poverty in rural areas. In the education sector, Vietnam has obtained impressive results compared with those countries with similar economic development: over 90 percent of the working age population is literate; more than 98 percent of children of primary school age attend schools; and the enrolment rates for boys and girls are more or less similar.

The promotion of learning and respect for teachers are among the core traditional values of the Vietnamese people. In the past, there was a perception among intellectuals in Vietnamese society that a teacher's position was higher than that of one’s parents and only lower than the king’s. Ordinary people understood that they should give their children opportunities to learn in order to know how to be human beings.

The biggest challenge faced by the Vietnamese education system is the contradiction between the goals of system growth/expansion and the continual improvement of quality on the one hand, and limited resources on the other. During the long pre-reform period, the education system relied on the state budget for its resources. In making the transition, the government wished to mobilize all possible resources in society for educational development. Past evidence proves the efficiency of this policy. According to the Education Law, financial sources of investment for education comprise: the state budget; charges and fees (tuition fees and admission fees); income from consulting work, technology transfer, production, business and service activities of educational institutions; investments from domestic and international organizations; educational development registration fees; and other funding from domestic and international organizations and individuals as regulated by law.

A number of Vietnamese universities have taken advantage of international funding sources to establish high-tech and science centres so as to improve the quality of training and research. These centres have put emphasis on science and technology in priority areas such as biotechnology, new material sciences, information technology, automation, etc. These centres have been provided with modern and up-to-date equipment.

Moreover, Zink (2009) explains that during the 1950s and 1960s, Vietnam was engaged in higher education exchange with both China and the USSR, including its satellites. Therefore, the two science education models being considered were the Soviet and the Chinese systems. The Chinese system was designed to achieve greater egalitarianism within Chinese society, and to foster home-grown science and technology that would contribute to greater Chinese independence from foreign interests. Meanwhile, the Soviet system fostered the creation of 'an educated elite' and sought to be a world leader in advanced technology. The Soviet Union's system of higher education and research found the hierarchies created by higher education to be an asset, and encouraged a competitive spirit that would drive the frontiers of technology forward. Ultimately, the Soviet system was adopted and adapted to the needs of Vietnam.

All in all, science in Vietnam is very strongly linked to national development and efforts to attain the status of an industrialized nation. This is evident from the statements of government officials, as well as from scientists' own beliefs about the purpose of their work. The Vietnamese government recognizes science capacity as a key component in its plan to achieve development goals. Going beyond mere recognition, they also invest in scientific equipment and finance the training of a new generation of scientists, both at home and abroad.

1.2.2. Lessons to Be Learned from the Case Countries' Experiences

As mentioned earlier, policy or strategic policy in this document refer to a standalone course of action, as of a national government in a country, intended to exclusively influence and determine strategic decisions, actions, plans and other matters regarding a set goal. In this case, this entails the Ethiopian Government ensuring the provision of efficient and effective STME with the view of enhancing the quality of education across all levels and meeting the labour force of the country.

Considering this definition, the following lessons could be drawn from the experiences of the countries outlined above:

- Education policy and practice are best informed by evidence. From the broader education policy, having periodically reviewed context-specific strategic frameworks, guidelines, plans or documents on STME is a priority for developed countries and emerging economies alike. There is no doubt that having a standalone strategic policy for STME at the national level could be a plus for a country. At the root of this are educational issues of wider concern, such as the framework of compulsory education, the content of science and mathematics curricula, the relationship between schools and colleges and their local communities, and a teaching profession that has been worn down by continuous policy reform and narrow accountability measures. Above all, the linkage of STME with key development sectors such as line ministries, professional associations and industries leverages the ultimate goal of ensuring efficiency and effectiveness.

- The case studies show that having a standalone STME policy document is not common. Rather, such relevant policy goals are embedded in the national education policy or written in specific action plans, directives, frameworks and the like. The effort of developing a standalone STME policy would entail coming up with measures endowed with the assurance of meeting the needs of the nation and supplying sufficient and high quality STM professionals. This vision is grounded in the development efforts of Ethiopia and the issued GTP-II and ESDP-V.

- Some of the observed measures used internationally to expand the STME workforce and that are useful for the development of Ethiopia's STME policy include:
  - Reforming school curricula to make science more accessible and attractive.
  - Improving the quality of teaching in mathematics and science in schools.
  - Increased pathways in STME studies and careers.
  - Enhancing public-private partnerships between industry, primary and secondary schools and tertiary institutions, and professional associations to improve student performance, enhance the relevance of instruction and raise enrolment.
  - Increasing participation rates of women.
  - Providing incentives to businesses to hire more staff in targeted fields and occupations, particularly researchers.
  - Working collaboratively with associated line ministries such as the MoST, industries, professional associations, higher learning institutions and both local and international NGOs to enhance STM learning.
  - Increasing government support for graduate studies, including PhD programs and students.

- The case studies also teach us that there may be critical challenges facing science education based on four main elements,[9] from which we need to learn so as not to repeat similar mistakes:
  1. There is evidence of students developing increasingly negative attitudes to science over the course of secondary school. This tends to be informative of the local situation in Ethiopia and requires a strategic approach to STME to mitigate the problems related to negative attitudes.
  2. There is decreased participation in post-compulsory science subjects, especially the enabling sciences of biology, physics, chemistry and higher mathematics, and hence there must be efforts to address these issues through the outline of a strategic approach.

3. There is a shortage of scientifically qualified people in the skilled workforce and hence there should be a strategic approach to produce capable, competent and qualified professionals to match the country's demands.
4. There is a shortage of qualified science teachers, which needs to be a focus area in both pre-service and in-service modes, since teachers are the most indispensable agents in implementing the strategic policy guidelines as well as other inputs.

The abovementioned points provide confirmation that improving STME in Ethiopia is critical and that the lessons extracted from the global experience are of paramount importance in framing the country's strategic policy and in identifying experiential milestones for the development of strategic goals.

2. STME IN ETHIOPIA

The Ethiopian education system consists of two cycles of primary education; two years of general secondary education; followed by either a university preparatory program or technical vocational education and training (TVET). Mathematics is offered separately all the way from kindergarten through secondary school, and science is given as environmental science (integrated form) in the first cycle of primary (Grades 1 to 4). It is further offered as integrated science in Grades 5 and 6, and separately as biology, chemistry and physics thereafter. Ethiopia offers early specialization, offering courses in biology, chemistry and physics starting from Grade 7. Thereafter, students study STM and related subjects, including physical, mathematical and engineering science; life science and health; teaching, business and economics; and other related fields.

In addition, recently the Ethiopian government placed special emphasis on science, technology, engineering and mathematics education. One example of this is the setting of the target of a 70:30 enrolment mix, where 70% of students enrolled should be in science and technology and 30% in social sciences. In addition, the government has established the Centre for Strengthening Mathematics and Science Education in Ethiopia (CSMASEE) under the federal MoE, which is responsible for science and mathematics education across the sector. Ethiopia's membership in SMASE-Africa, a regional association where African countries exchange skills, experiences and issues in teacher education in mathematics and science, which it joined in 2007, later evolved into more collaboration between Ethiopia and the Japanese government, which led to the launch of the CSMASEE.

Moreover, the Ethiopian Government has initiated a number of guidelines and strategies to deal with outstanding issues regarding STME. Some of these include:

I. The Concept Paper and Strategies for Improving Science and Mathematics Education in Ethiopia by Curriculum Development and Implementation Core Process (2010).

This concept paper examines the problems facing science and mathematics instruction in Ethiopia and proposes actions to be taken at federal, regional and school levels. In particular, it outlines measures to make mathematics and science instruction more interesting and meaningful, and to implement proper evaluation mechanisms. In fact, given its relevance and detail, this document should be a key part of the STME strategic policy.

II. The document Strategies for Improving the Teaching and Learning of Science and Mathematics in Ethiopia (2010).

III. The National Pilot Project for Strengthening Mathematics and Science Education in Ethiopia (SMASEE), Project Document, MoE, February 2011. This document consists of a detailed project design matrix and plan of operation. Moreover, it includes the Memorandum of Understanding for the formulation and commencement of the project in three selected regions.

IV. The Action Plan for Improving the Teaching and Learning of Science and Mathematics in Ethiopia (2010).

V. SMASEE Teacher In-Service Education and Training (InSET) Guidelines (prepared by the National Mathematics and Science Improvement Centre, MoE, June 2014). This document, after outlining the rationale and objectives of the guidelines, tries to build a SMASEE InSET model that includes a training structure, content, implementation body, sensitization, monitoring and evaluation. It then gives step-by-step guidelines for preparing and implementing centre-based, readymade and needs-based InSET at national, regional, cluster and school levels. The document could be part of the overall STME strategic policy for increasing the quality and quantity of teachers.

VI. The Education Sector Development Program (ESDP) has always emphasized the need to deliver quality education at all levels. The ESDP-IV, which was implemented 2010/11 – 2014/15, had as its goal to "strengthen the focus on sciences and technology". It unequivocally states that "Education with science and mathematics as its major component determines the level of prosperity and welfare of the people and the nation. In order to realize this conviction, the Ministry of Education is trying to enhance science and technology through introducing 'high quality curricula' at primary and secondary schools" (ESDP-IV, Program Action Plan, MoE). This policy will greatly reinforce and complement what is already in place.

Despite all of these efforts, Ethiopian students continue to perform poorly in science and mathematics. According to the National Learning Assessments (NLAs) conducted every four years from 2000 through 2012, results have not improved. The results are presented below in aggregate for the national level by grade level and year.

Table 1: Average composite scores (%) in NLA by year and grade (NAE, 2000, 2004, 2008, 2012)

Grade	2000	2004	2008	2012
4	47.9	48.5	40.9	40.6
8	41.1	39.7	35.6	35.3

These findings, reported in terms of aggregate grade level achievement, underline two things: a) the results at both Grades 4 and 8 and across the years is below the national standards of 50% set by MoE; and b) the results do not show improvements across the years and as the grade level increases; in fact they show decline. To provide more details, Table 2 presents achievement by subjects across grade levels and years.

Table 2: Average composite scores (%) by subject in NLA by year and grade (NAE, 2000, 2004, 2008, 2012)

Grade	Subject	2000	2004	2008	2012
4	Mathematics	39.31	39.69	40.3	NA
	Environmental science	48.14	51.74	42.6	NA
8	Biology	47.16	41.34	38.3	42.1
	Chemistry	40.27	40.10	34.7	NA
	Mathematics	38.23	40.93	34.1	25.53
	Physics	NA	35.32	32.2	34.45

The results of the NLA are even lower at the higher grade levels when it comes to science and mathematics subjects. The NLA for Grade 10 conducted in 2002 E.C. (2009/10), as presented below, also shows that the percentage of students in Grade 10 who achieved results above the national standard of 50% was very low. This underscores the magnitude of the problem in terms of achievement and quality in the subjects of science and mathematics.

Table 3: Percentage of students who scored above the cut-off point in Grade 10 (2010)

Subject	Percent achieving 50% and above
Mathematics	14.7
Biology	24.8
Chemistry	17.1
Physics	10.1
Average	13.8

Source: MoE (2011), Education Statistics Annual Abstract

Beyond the NLA reports, several researchers also conducted studies related to science and mathematics learning, achievement and the overall status of these disciplines. As revealed by several studies (Ayele, 2010, 2014; Melese, 2014):

- Students avoid science classrooms and laboratories, do not consider them a priority, and previous efforts have only provided a starting point to giving emphasis to science and mathematics education without solving the current challenges that students have.
- Lack of interest in science leads students to fail in the subjects, and this in turn contributes to them repeating class years and eventually dropping out of school.
- Even though the number of graduates in the science fields is increasing, a significant number of graduates in science and mathematics are studying other fields and abandon their STM studies.

Assessments and evaluations of the existing science and mathematics curricula also indicate that they encourage passive learning, especially during implementation (Solomon, 2008); that there is a grave shortage of facilities and that there is less practice in utilizing the available resources; that mathematics and science are perceived as rather difficult subjects (Eshetu et al., 2009); that most of the contents are not presented in a simple form, are beyond the understanding level of students, and do not reflect local values and culture (Reddu, 2015); and that continuous assessment methods and active learning are not given enough emphasis (Berhanu, 2010).

Apart from the reported challenges associated with STME mentioned above, the research team for this report undertook a SWOT analysis to identify strengths, weaknesses, opportunities and threats of the current state of STME in Ethiopia and identify essential strategic approaches to mitigate problems and ensure the further development of the nation. Table 4 presents the results of the SWOT analysis.

Table 4: Findings from the SWOT analysis

Internal (MSIC, MoSt and MoE)	**External**
Strengths – Internal positive attributes of current STME, and that are helpful in terms of achieving the country's overarching STM objectives. o Strong support from ministry officials from the MoE, including the minister, and good overall commitment of the Ethiopian Government. o Serious follow-up, as STME is given due emphasis as part of the GTP-II and ESDP-V. o Several initiatives have been undertaken by the MoST and MoE that have laid the foundation for this strategic policy for STME o Increased number of universities,	***Opportunities*** – External factors that can help STME to achieve its objectives o Availability of Ethiopian Science Academy. o Ethiopia is a member of the East African STME Centre. o MoE is working with the Ethiopian Broadcasting Company (EBC), and the educational media under the MoE. o Establishment of a trial centre at Wolayta. o Strong support from government, with particular attention given to STME. o Willingness of development partners

teacher education colleges and their respective research outputs. o Establishment and capacity building of CSMASSEE with support from JICA. o Mathematics and Science Improvement Centre (MSIC) has mobilized STME issues at school, regional and national levels, which helped to outline the problem and its magnitude. o Training and awareness creation programs (on STME issues), including for policymakers, have been provided. This strategic policy for STME started from something and not from zero. o Internal capacity at project level has progressed, which started from Grades 7 and 8, and now includes Grades 5, 6 and 9. o Pedagogical gaps among teachers were identified, and a training curriculum developed. Modules were developed by internal experts and trainings provided to teachers. o Trainings to teachers were given at regional level, and comparative studies were carried out, whose results showed that trained teachers progressed more. o Regional training centres were established. Capacity building efforts have been started. Teacher training colleges also started working with the CSMASEE. o Establishment of the CSMASEE and its advancement from a case team to a fully-fledged centre. o Professionals in the CSMASEE have been capacitated, although this needs further improvement. o Working with development partners; going on training and experience sharing visits abroad. o Teachers received trainings on physics education from Institute of Physics (IOP) working with IOP is a positive development. o Issuance of trainings on STME pedagogy. o While doing the baseline survey and	to work with MoE. o GTP promotes STME. o ESDP-IV has included key activities on STME. o Schools have begun to establish STEM centres. o Establishment of professional associations (chemistry, physics, etc.). o Establishment of STM-specific universities. o Availability of STME PhD and MSC programs at AAU and the launching of the same at other universities (such as Bahirdar, Mekelle, etc.). o Commitments from regional states. o The selection of Ethiopia as a learning champion. o Availability of STME research centres (Geo-observatory Centre, Mekelle Space Science, etc..)

assessment for the strategic policy for STME, we learned that trainings are making impact. o Classroom assessment tools development and implementation is being carried out. o Trainers of Trainers training given for secondary school teachers and this has been cascaded to ensure sustainability.	
Weaknesses - Internal negative attributes of current STME, and that are harmful in terms of achieving the country's overarching STM objectives o Piecemeal and non-integrated interventions. o Lack of experience in involving professional associations. o Gaps in terms of teachers' and overall societal attitudes towards STME. o Teachers failing to cascade capacities after receiving trainings. o Inconsistent establishment of the CSMASEE across regions. o Lack of production centres to supplement science laboratories. o Gaps in terms of using low-cost laboratory concept and expectations of having fancy laboratories. o The pilot project for SMASEE that was initially conducted in three regions (Oromia, Amhara and Addis Ababa) did not progress well to other regions. o External relationships limited to few institutions and countries. o Lack of sufficient budget to expand and support regional training centres. o Limited capacity of experts compared to the task required for Ethiopia to excel in STME. o Centre–university linkages are at an early stage of development. o Poor experience sharing system; including the centre, universities, College of Teacher Educations and schools o Lack of proper incentive mechanisms.	***Threats*** - External factors that are harmful to STME in terms of achieving its objectives o Role confusion and conflict between structure at national level and regional level mandate and willingness to implement. o Absence of a clearly defined structure, which may lead to collapse of existing initiatives. o Regions not allocating a specific budget for STME. o No strong database to supply appropriate data for research. o Increasing number of school children may prove a challenge for providing quality STME. o High turnover of STME teachers. o Leadership problems in some cases. o Increasing cost of labs and equipment. o Poor storage and disposal systems for available and used lab equipment. o Teachers' capacity and their available time to engage in lab activities. o Failing to own and work in labs due to the absence of lab attendants and lab technicians.

o Weak dissemination of efforts, findings and directions. o Student performance remains poor. o No proper data and information flows from collaborative organs: centre–school, university–school, university–centre, etc. o Student STM capacity is not at the level the country has been expecting. o Poor prior effort in terms of identifying and working on STME. o Weak functioning of school labs. o Some regions have not established a structure that can implement STME strategies. o Role of stakeholders is not properly defined. o Poor monitoring and evaluation system. o Lack of proper management and disposal of lab chemicals.	

In order to address these issues, the Ethiopian education system has gone through several reforms. The General Education Quality Improvement Program (GEQIP) is an example of this. Supported by the World Bank, the objective of the GEQIP[7] is to improve the quality of education at all levels, with a specific focus on "improving learning conditions in primary and secondary schools and strengthening of institutions at different levels of educational administration".

The efforts taken by the government have led to several reforms and some initiatives. These include:

- A competency-based approach.
- The development of a new syllabus format.
- Organizing the Minimum Learning Competency (MLC) into themes or competency areas.
- Contents of textbooks and learning materials reduced and simplified.
- New contents introduced to teachers and students.
- Design of active learning methods.
- Inclusion of qualitative learning and peer instruction.
- Overarching issues have been integrated.
- Inclusion of scientific enquiry and life skills.

Although it is difficult to measure the exact impact of these reforms, it is believed that they will bring about positive long-term impacts on STME in Ethiopia. Despite these reforms, the persistence of low scores for students, the gaps in the competencies of experts in these fields and the problems identified by research reports must be addressed. In addition to the problems associated with lack of competence, enhanced achievement and attainment of quality education, the integration of technology and the teaching and learning of technology itself is lagging far behind expectations. In this respect, Kassa (2015), in his study entitled ‘Integrating technology, content and pedagogy for enhancing quality of education’, reported that technology is not perceived as being an integrated component in teaching content and for those who perceive technology as a tool for teaching-learning they are not keen on using it. The use of ICT in education has also not gone much further than the use of a plasma TV, although the government has recently started to promote the use of Internet in schools in order to utilize technology for teaching-learning purposes.

All in all, irrespective of the ongoing efforts of the Ethiopian Government and the MoE, the quality level of STME is critical and needs to be addressed meticulously. The strategic policy is expected to direct plans and actions through the collaborative efforts of all stakeholders, with the view of mitigating the problems and ensuring a shift from the current challenging situation towards an achievable state of making science and mathematics learning part of daily life and fun in its own right, and of utilizing technology for advancing learning and backing development endeavours. This will also assist in managing efforts towards achieving the government’s intentions of producing an educated workforce that will be fit to meet the requirements of the country’s development plans, and which can adapt, develop and innovate with the help of scientific findings and useful technologies, and can identify advancement approaches.

3. CHALLENGES OF AND RATIONALE FOR STME IN ETHIOPIA

For Ethiopia to continue on its path of rapid economic growth and ensure a progressive economy in the future, a workforce of scientifically and technologically literate people is required. With identified shortages across the engineering, science and medical professions, there is a growing need for a highly trained pool of 'quality' experts specialized in STM disciplines. However, the challenges of STME in Ethiopia include, beyond low achievement, negative perceptions about STME; the poor quality of the curriculum and pedagogy; grave shortages of facilities and equipment; large class sizes; poor assessment practices; a mismatch between STME and local values and culture; poor attention to preschool and general education levels; a gap in terms of collaborative work between stakeholders; and low levels of persistence. The attitude and motivation of teachers is furthermore critical.

3.1. CHALLENGES AND ISSUES OF STME IN ETHIOPIA

The advancement of science and technology in a country needs to address critical issues and challenges that hamper proper STME. From the literature review and subsequent consultations with stakeholders, the following specific challenges and issues have been identified as being fundamental when it comes to considering the development of an STME policy:

A. The belief that science is universal and powerful justified its education in schools. Slowly, such beliefs and practices were extended to all parts of the world, including Africa. During the early years of the 20th century, science and mathematics education, and education in general, was increasingly justified on the basis of its relevance to contemporary life and its contribution to ensuring a shared understanding of the world on the part of all members of society. However, in all of the efforts to define science and to teach it in schools, it remained rooted largely in Western history and culture. The current mechanical sciences can be called Western, given their historic origins in Ancient Greek and European culture. Therefore, as place-based education has become so critically important at present, there is a need to organize science education so that it can fit the Ethiopian context and assume its transformative impact. Such reorganization requires an understanding of what transformative science is – that it is of significant importance to have science based on the local context, to develop indigenous knowledge systems, and to entail observable application in society – and how we should deliver it in the form of active learning.

B. African people have "ample evidence of science education that happens every day in our homes and communities, which is often ignored or not seen as 'science'". The same is true for Ethiopia. Many African writers argue that "only a broad view of science that integrates the accumulated knowledge, values and customs of the people will help provide a holistic development of societies". The expansion of science to include local/traditional knowledge expands the freedom that is needed to make development happen. The outcome will be the promotion of creativity, innovation and problem solving and the discouragement of the pedagogy of rote memorization and recall that currently prevails in Ethiopian schools.

C. The above two critical issues have resulted in the lack or total absence of context-specific policy to guide implementation and ongoing practice in the training of science and mathematics teachers in colleges and universities. The mismatch between what is required and what is actually taking place, as a consequence of an emphasis on content transmission at the expense of the pedagogic training in the skills required to teach science and mathematics, has deprived teachers of critical and relevant scientific modes and practices. Teachers lack both the skill and the motivation to use laboratories or utilize locally available materials in their science classrooms.

The Mathematics and Science Improvement Centre (MISC) conducted a Baseline Survey from May to June 2011 to explore the current situation of teaching and learning in mathematics and science lessons of Grades 7 and 8 in Ethiopia. The results showed that teachers have knowledge and skills gaps in terms of lesson planning, active learning methods, facilitation and assessment skills.

These are persistent practices based on the traditional approach to teaching science and mathematics. With a strategic policy to lay out a guide on how teachers should be trained, how they need to approach science and mathematics and keep track of their own professional development, their effectiveness and efficiency will be increased. This has been witnessed in Kenya with the support of JICA, a project that ran from 1998 through to 2008, which has benefitted thousands of science and mathematics teachers. In total, over 1200 educators from 28 countries have undergone training in Kenya. Such a tracked and focused intervention is therefore essential in the Ethiopian context.

Understanding this scenario, the MoE launched the MSIC in 2010/11 as a case team under the Teachers' and Education Leaders' Development Directorate, which later developed into a centre for strengthening mathematics and science education, with the role of strengthening and empowering science and mathematics learning in Ethiopia to help ensure better achievement. However, the centre faces several limitations in terms of staffing, the provision of resources including budgeting, establishing a seamless link between the centre and regional education bureaus, and overall structural organization.

Moreover, the salary structure of teachers across all disciplines is set at the same scale. Either the salary structures or possible incentives need to take into consideration the extra time and energy that science teachers spend in the laboratories and the field. They should be guaranteed good health coverage with the view of addressing issues of security and safety, as they deal with chemicals and disease-causing organisms. In this regard, there is an urgent need to reorganize the way that science teachers are recruited, trained, assigned and incentivized.

D. The making of a science curriculum that is transformative and locally relevant needs to include the concept that 'science is fun'. One of the reasons that students avoid science and mathematics learning is that they do not find any joy in learning it. Despite its relevance to their lives or their hopes of being a well-paid doctor or an engineer, most students tend to join social science streams and avoid the natural sciences, thinking that the former is easy and fun to learn. Science education in Ethiopia needs to be reorganized so that it is relevant and fun to learn, and therefore attractive to students.

E. By the same token, Tuge (2008) states that teaching mathematics in Ethiopian schools is more explanatory and prescriptive, focusing on transferring rules and formulas, at the expense of taking an innovative approach to thinking logically and reasonably to enhance applicability and creativity. The focus is on teaching what to think (content) and not how to think. There is little evidence of the use of challenging, unfamiliar and open-ended problems in the mathematics curriculum or in classrooms in Ethiopia. In almost all schools, mathematics textbook exercises are used rather than (open-ended and unfamiliar) problems. A change in the way that science and mathematics instructions are given at school level requires a corresponding change in the structures, methodological approaches and entailing budgets of schools. The need for a policy framework to make sure that science and mathematics are delivered with supportive practical inquiries, practices and innovative pedagogies is timely. Smaller class sizes (e.g. when conducting laboratories), well-equipped laboratories, well-written manuals and guidelines that support innovation and creativity, a budget for purchasing experimental resources and funding fieldtrips, etc. are inescapable if schools intend to reorganize themselves for the proper delivery of STME. Efficient systems for purchasing, storing and disbursing materials are of paramount importance within the school setup. STME is an outdoor activity just as much as an indoor one. Children should be presented with various opportunities to learn and do science, both at school and in out-of-school settings. The establishment and expansion of zoos, science centres and museums (of agriculture, nature, history, etc.), and the establishment of children's centres in each of them so that students can colour in, put puzzles together, listen to lectures, watch videos (whenever available), play games, etc. will all greatly help scientific literacy. Community organizations and institutions should have centres of education where students can regularly come and interact. In Ethiopia, such facilities are not usually present, and this needs to change.

F. Early experiences affect later education outcomes. Providing young children with research-based mathematics and science learning opportunities is likely to pay off with increased achievement, literacy and work skills in these critical areas, as well as laying the foundation for further learning. Technology is not only about using products such as computers and other apparatus; it is also about thinking how to innovate using locally available materials in delivering teaching and learning. These days, technology has become part of daily life and hence it is needed to improve the quality of education. Providing young children with access and opportunities to experience innovative technologies, either utilizing readymade technologies or innovating with locally available materials, is of paramount importance. It also seeks to associate use with content in science and mathematics.

G. The subjects of STM – despite their independent identities – need to be integrated for successful educational achievement. Hence integrating technology into the teaching-learning of science and mathematics is important. In addition, targeting the aim stated in the policy document of Ethiopia's MoST, "Ethiopia [must] entrench the capabilities which enable rapid learning, adaptation and utilization of effective foreign technologies by the year 2022/23". Supporting young children to develop the ability to utilize foreign technologies is of paramount importance and demands focus.

H. As teachers play an indispensable role in enhancing STME, their training, preparation and professional development, both during pre-service and in-service modalities, requires an important focus. Developing the positive attitude of teachers is also another critical pillar that needs to be addressed.

I. As STM are part of our daily lives, and the effective utilization of STME demands societal involvement, is it essential to capture the role of society in realizing STME. Varying centres of STME, museums, science culture development camps, etc. can only be efficiently realized when society takes part in their development, management and sustainability. Thus the involvement of society is also another dimension that needs to be addressed.

3.2. RATIONALE FOR STME IN ETHIOPIA

Ethiopia has witnessed rapid and double digit economic growth for over a decade. After finalizing the first Growth and Transformation Plan (GTP-I), the Ethiopian Government has launched its second, the GTP-II (2015-2020), aimed at boosting the economy and transforming Ethiopia into a middle-income country by 2025. The main objectives in the GTP-II are economic growth and industrialization. In order to materialize such a national vision, this requires transforming the country's economy from one that is reliant on agriculture to one based on industry. Such an economic transformation can only be achieved through the application of science, technology and innovation as the major instruments. Additionally, sustaining such economic growth demands highly qualified and competent professionals in the fields of STM. The ESDP-V (2015/16 – 2019/20) envisioned the application of science, technology and innovation as the major instruments to create wealth; indeed, these fields have now taken their place as the foundation for achieving the long-term vision of transforming Ethiopia into a middle-income country. As a result, the Ethiopian Government has placed great emphasis on the importance of STME as an essential component of achieving the development needs of society, and for which the MoE is preparing this STME strategy.

The underlying assumption for this strategic policy is therefore that STM are the bedrock for the country's economic growth. While there are complex and diversified issues, problems and challenges, Ethiopia is striving to build up strong scientific and technological capacity. There are two overarching reasons for this. Firstly, the government intends to sustain the great strides that the country has taken in industrial expansion. And secondly, this is a need to fulfil the country's vision of becoming a mid-level income earning country by 2025. Most importantly, the MoST has set a vision of seeing "Ethiopia entrench the capabilities which enable rapid learning, adaptation and utilization of effective foreign technologies by the year 2022/23".[8] In order to realize this vision, the country requires a scientifically literate human resource base, which can be developed through proper STME. This, in turn, requires developing a context-specific National Strategic Policy for STME, which fits into the national Science, Technology and Innovation Policy and Strategy and the country's broader development goals.

Delving into the rationale outlined above, the level of organization required in the implementation of STME draws attention to the different levels of education, such as primary, secondary and tertiary. Children at early grades are expected to use (learning) technologies and other means for learning; by learning about and using technologies, this sets a foundation for knowing, identifying and making meaning of their surroundings. Young children at secondary schools are expected to use integrated STM in their learning and to delve into setting directions for their future career and ensuring learning towards meeting standards. Higher level students are expected to be more than users in either the separate forms of STM or their integration, and rather be focused towards the innovation and development of a new knowledge base to back up economic growth and overall national development.

4. MISSION, VISION AND OBJECTIVES OF THE STRATEGIC POLICY

4.1. MISSION

To strengthen the knowledge base of STM, to enhance basic science research and STME from preschool to post-graduate levels, and to understand and improve STME learning and applicability.

4.2. VISION

The vision of this Strategic Policy for STME is based on the national vision: "To see Ethiopia become a country where a democratic rule, good governance and social justice reigns upon the involvement and free-will of its peoples, and once extricating itself from poverty becomes a middle-income economy as of 2020-2023".

Accordingly, this strategic policy vision is to "see the country build a well-qualified and increasingly diverse STME workforce who can lead sustainable development in STM-related sectors and to fulfil the country's workforce needs".

4.3. OBJECTIVES

Major objectives of the strategic policy are:

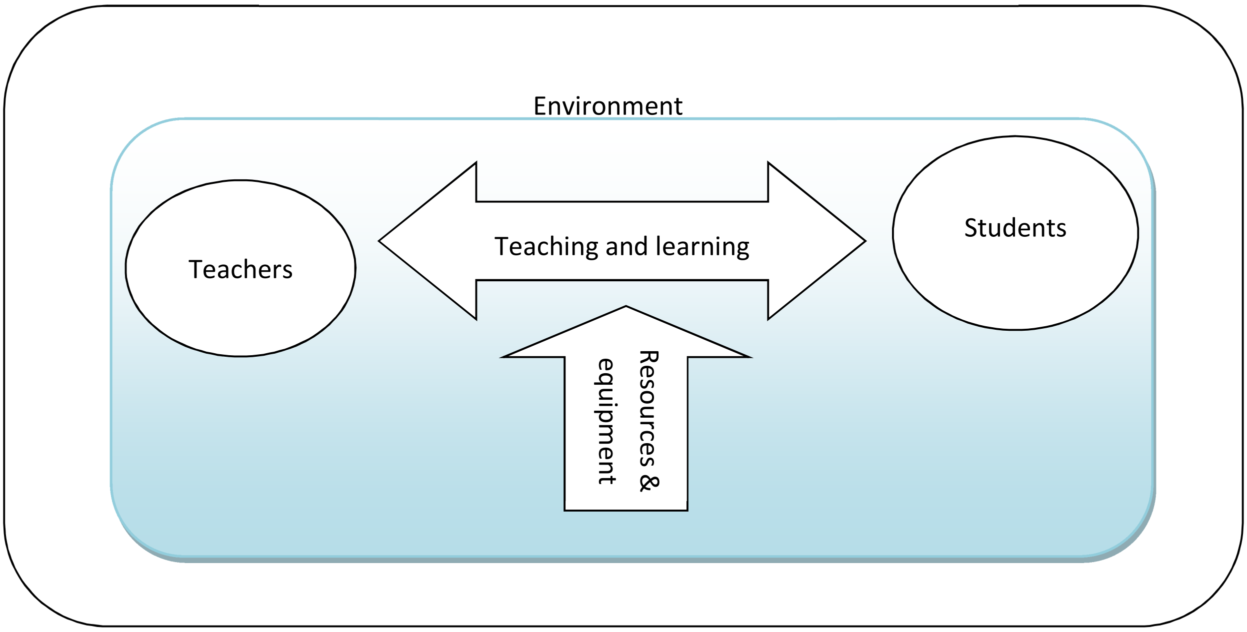
- To strengthen STME in schools at all levels. This objective focuses firstly on the initial professional development of teachers or pre-service training, and secondly on in-service training and on the continual professional development of teachers.
- To improve the provision of STM resources. This focuses on plans to identify and distribute STM textbooks, and to provide laboratories with equipment and chemicals and other resources to schools.
- To provide programs to support students in STM. This strategy includes a range of initiatives to improve student achievement through both in-class and supplementary programs aimed at the improvement of students' achievements in the short- and long-term.
- To enhance process skills as well as outputs. The strategy aims to enhance research skills and positively influence the teaching and learning of STM in schools, and to influence the environment through the contribution of STM results.
- To improve the management of STM teaching and learning. This strategy aims to ensure that there is a positive and conducive environment for STME in schools and districts.
- To build up STM as part of the culture. This strategy aims to launch centres, museums and work stations in several places and to promote STME.

5. POLICY DIRECTIONS AND IMPLEMENTATION STRATEGY

The strategic policy will provide a shared roadmap to guide and ensure that the MoE and regional education bureaus, in collaboration with other actors such as the MoST, have the best potential for making a substantial impact in key priority areas. This strategic policy background document has been developed after carefully considering the national context; reviewing documents for policy input, and the reports of researches related to science and mathematics education; and in consultation with stakeholders and actors starting from high level leadership to teachers in schools, researches in the field, and institutions that have close functions with STME.

Accordingly, this strategic policy centres its foundation on the fact that teachers and learners are the primary actors in STME, supported by but not entirely dependent on resources, and influenced by a range of learning environment factors and role players. The following model has been adopted and is contextualized to conceptualize the selected and prioritized pillars of the STME strategic policy in the country.

Relationship between actors to enhance STME



The model works from the assumption that the nature of the teaching and learning behaviour of teachers and students determines the success of any education system more than any other factor. In order to make this strategic policy document implementable, other factors such as resources and the learning environment are considered important, but should not be taken as definitive. The relationship among all these factors is also critical for the overall functioning and implementing ability of the strategic policy.

Three broad critical policy pillars are identified, based on the national STME SWOT analysis and the review of the characteristics of the countries selected as benchmarks because of their best practices. The strategic policy pillars also take into account the environment in which things work, and the implementing agents: teachers, students and resources (including knowledge base and management). Accordingly, the strategic pillars and their specific strategic options are presented in the following sub-sections.

5.1. ESTABLISH AND ENHANCE ACCESSIBLE AND QUALITY STM TEACHING AND LEARNING

The 1994 Ethiopian Education and Training Policy states that one of the country's foci is to promote and disseminate science and technology. The policy's General Objective # 4 specifically indicates “bring[ing] up citizens (…) who show [a] positive attitude towards the development and dissemination of science and technology in society”. Subsequent programs such as the ESDP-IV and the current ESDP-V have specific program components focused on promoting and disseminating STME in the country. This Strategic Policy on STME aligns not only to the country's education and training policy but also recognizes the centrality of teachers in enhancing and improving STME in Ethiopia, and it also envisions the role that society can play in realizing the intentions of the strategic policy.

The strategic policy pillar of society should be put in place by a variety of approaches, launched through the establishment and enhancement of multi-stakeholder partnerships – at both school, kebele, woreda, regional and national levels – to bring together government (all sectors concerned, from local/regional ministries of education to those responsible for science, technology and research, and authorities with responsibilities from national to local level), industry, research, communities and the media – who are so important in spreading messages to wider society and changing the vision of and towards STME. These partnerships need to be sustained over a long period of time to bring about real change on the ground at the level of students and teachers, and should be underpinned with ambitious and strategically built plans to ensure coherent actions across the various stakeholder groups. The focus should be on the identification and sharing of approaches that bring measurable change to students, but also to develop new approaches where a needs analysis identifies gaps.

Following are outlined important issues and strategic options regarding the establishment and enhancement of STME teaching and learning.

5.1.1. Curriculum Development and Revision

Over the past years, the nature of school science and mathematics education and school curriculum frameworks has been the subject of much scrutiny, particularly regarding the fact that it is rooted in promoting rote memorization, and is filled with too much subject content that does not require analytical and synthetic skills. Keeping the curriculum and assessment up to date is an essential component of effective STME policy and strategy. Pedagogy is also important, with the literature highlighting the importance of teacher content knowledge as well as teaching practices. These days, education literature promotes the integration of technology, content and pedagogy for the efficient and effective delivery of STM subjects. An inquiry-based, practical and relevant approach to STME teaching and learning produces the most positive outcomes.

When reviewing the curriculum, the most important issues to be considered include shifting from a content-based to an analytical and synthesis approach; the integration of indigenous practices and skills; and the inclusion of interactive assessment methods and systems. This does not suggest throwing out the existing curriculum; but the curriculum does have to be dynamically reviewed, modified and updated to suit the planned, implemented and achieved nature of the Ethiopian Government’s intentions to ensure development.

Another essential issue in this regard is that the curriculum should be designed in such a way that it promotes and links itself with informal learning to expand mathematics and science beyond the classroom. Many public and private institutions, such as museums, science centres, and after-school programs provide valuable out-of-class experiences that demonstrate how mathematics and science connect to everyday life and careers, and allow students and teachers to expand their skills. These programs are proving to have a positive effect on interest and achievement in STME. Evidence shows that these designed yet informal settings can and do promote science learning. To ensure these goals, there is a need to:

- Establish and expand science and technology museums in different regional states.
- Ensure the integration of science fair projects within the school day by both schools and local ministries of education.
- Promote student-led STME exhibits combined with competition elements to reward the best submissions.

5.1.2. The Indispensable Role of Teachers in STME

There is a widely accepted education maxim about teachers: "The quality of an education system cannot exceed the quality of its teachers". Most importantly, the quality of STME in the school system is heavily dependent upon teachers' competencies. Researchers have clearly shown that the quality of teaching matters for student learning. Teacher quality has been consistently identified as the most important school-based factor in student achievement, and teacher effects on student learning have been found to be cumulative and long-lasting.

Overall, there are two generally recognized issues: getting the right people to become teachers and an ongoing process of professional development to develop teachers into quality instructors. There is wide agreement that this applies equally in Ethiopia as in any other country. Emerging critical issues in this regard are indicated below.

5.1.2.1. Building a Strong Teacher Profession

An effective STME teaching and learning system needs a sufficient number of effective teachers at all levels. Regarding numbers, Ethiopia's ESDP-V, like the ESDP-IV, has retained a target programme mix of a 70:30 ratio of science and technology programmes to social and human science programs. Meanwhile, amongst the important objectives that the strategic policy must address are the following:

- The quality and skills of mathematics and science teachers must be increased. This will require the strategy of both marketizing and incentivizing STM teaching in order to make the profession appealing. Centres for science learning need to be established that will provide the chance for students to learn science from daily activities and the informal knowledge in the community. Teachers must also be given practical support such as overtime pay (for extended stays in the laboratory, in the field or offering tutorials), workplace insurance, etc. Finally, they have to be shown clearly what the benefits of becoming an STM teacher are.

- In Ethiopia, there are 20 universities and one university college that train teachers for secondary schools, and 36 colleges for teacher education and one university college that train teachers for primary schools. In addition, standards for teachers are issued by the MoE, and there is a requirement for an assessment by the Center of Competency (COC) upon completion of teacher education. An effective system should deliver new teachers who have a standardized set of instructional skills and a uniformly high level of mastery of STM. Hence, there is a need to develop common core standards that will require teacher education institutions to incorporate their innovative approaches to STM.

- The strategic policy will (should) focus strongly on strengthening the existing in-service policy and implementation plan, as well as reviewing, implementing and managing it, involving the appropriate institutions and role players.

5.1.2.2. Instructional Skills, Content Mastery and Attitude

In the same way that the content design of all education and training curricula revolves around a balance between skills, knowledge and attitudes, the STM strategic policy recognizes that the professionalism of teachers is also a balance between a set of professional instructional skills, mastery of the content to be taught by the teacher, and a set of positive attitudes in the teacher, as these are all inextricably linked when determining professionalism in teachers. The impact of teacher attitudes on teaching and working with children cannot be underestimated. This strategic policy will (should) therefore address all three aspects in growing teacher competence and confidence. The following recommendations are made.

- Most teacher development has focused on skills and content mastery – the hard technical STM issues – while avoiding the soft issues such as morale and the attitudes of teachers. The STM strategy needs to include the boosting of morale, and the development of the aspirations, commitment and enjoyment of teaching among STM teachers. Without a shift in attitudes towards being willing and enthusiastic participants in an STM strategic policy, the chances of success are diminished. Part of this requires the establishment and expansion of zoos, science centres, museums (for agriculture, nature, history, etc.) and establishing children's centres so that students can colour in, put puzzles together, listen to lectures, watch videos (whenever available), play games, observe practical innovations, etc. All of these activities help scientific literacy. There is also the need to establish community organizations and institutions that have centres of education where students can regularly go and interact. This can be partly done through the provision of sufficient resources and by creating 'science for fun' activities within schools. Running apprenticeships for teachers and considering incentive mechanisms for the innovative efforts of teachers and those involved in promoting STM is also useful for drawing the attention of society and promoting a positive attitude of those involved in STME.

5.1.2.3. Managing and Measuring Teacher Competence

A campaign that seeks to improve the quality of teaching relies on accurate data in order to establish what improvement is needed and where, what kind of interventions are necessary, and whether interventions are making a difference. There is no baseline data currently available on STM teacher competence in Ethiopia. The recent competence measures include certification and biannual performance evaluations. Although teachers may be evaluated biannually, there is no aggregated data to show the levels of competence among STM teachers. The STM strategic policy will need to (should) include systems and processes that enable effective research, monitoring and evaluation. The measurement of teacher competence may carry certain challenges, but there are successful models for how they may be managed. Some examples include the interpretive model, structural model, COC model, etc. Among these, the interpretive model will probably work best in the Ethiopian situation, since schools are led by weredas and Parent – Teacher Associations (PTAs), and there is a need to involve society in promoting STME.

5.1.3. The Strategy for STM Teacher Pre-Service Education and Training

On completion of pre-service teacher training, there exists no standardized method or national guideline for evaluating teacher competence. Region-specific approaches are applied and this has an impact on the consistency of knowledge and skills among new teachers graduating from colleges for teacher education and universities.

The following interventions are targeted for Initial Professional Education for Teachers (IPET):

- Setting a standard for the IPET curriculum: The MoE/MSIC will engage with all higher education and training institutions and other role players to agree on setting a standard to ensure that all new teachers have achieved the minimum level of competence with respect to STM teaching. This will apply specifically to initial training and not to post-graduate training. The strategic interventions for this will involve commissioning a committee from the MoE, local higher education institutions and other selected experts to propose a new teacher training curriculum vis-a-vis the set standards. The target will be to implement either a standard-based curriculum or a standardized curriculum by the end of the ESDP-V period.

- Introducing an induction program for new STM teachers: The MoE will work with higher education institutions to develop a program to assist new teachers to integrate effectively into the school system. This will involve reviewing current school placement practices and investigating a support system for new STM teachers. A standardized school-based induction system that includes on-site mentors for newly employed first-time teachers will be explored. This strategy requires reviewing the existing induction program, reviewing the modules, drawing attention to including out-of class efforts, and making STM part of school culture.

5.1.4. The Strategy for Teacher In-Service Education and Training (InSET)

According to the ESDP-V, in-service training for all teachers will be provided through a targeted programme of continuing professional development (CPD). The approach to CPD is conceptualized as a school level, peer-led professional excellence strategy, consisting of reflective activity designed to improve an individual's values, knowledge and skills. It is designed to support teachers' individual needs and to improve professional practices. CPD will be delivered at three levels: external expertise, school networks and clusters, and school-based training.

The development of the CPD system by the MoE has/will have its own impact on the actions planned as part of this strategic policy document. According to the ESDP-V, one of the CPD priority topics is "The sciences, mathematics and the use of information and communications technologies for instruction". The STME strategic policy will need to align and coordinate with these initiatives and with existing and new policies and programs with respect to teachers. The following interventions are (should be) targeted for the CPD of STM teachers:

- Develop an STM teacher InSET policy, plan and consultative structure.
- Establish STM teacher data.
- Assessment of STM.
- Integrating technology, content and pedagogy.

In addition, the strategic policy envisions teachers, through CPD, to:

- Establish STME resources and materials from locally available resources and build up their capacity.

- Get involved in several centres of STM outside of school.
- Organize an STM day, exhibits and conferences.
- Get involved in conducting research.
- Disseminate STME.

5.1.4.1. STM Teacher InSET Policy, Plan and Consultative Structure

While it is generally acknowledged that InSET is a critical factor in improving STME, there is no regional policy, plan or structure for its effective implementation. Using existing resources, this STM strategic policy seeks to put this in place in an organized and systematic way in the regions. To this end, regional education bureaus need to establish InSET that helps them to function within their context.

5.1.4.2. STM Teacher Data

There is a need to establish and maintain an accurate database of STM teachers in Ethiopia. This will allow for the proper planning and management of training and for the measurement of its impact. The actions that need to be considered include compiling and updating the STM teacher database, as well as a competence database.

In order to plan training that addresses teachers' needs, the MoE/CSMASEE will undertake a needs analysis. This will include several things such as identifying gaps that require intervention and conducting gap-filling efforts, enhancing abilities through several modalities of capacity building strategies, and maybe also developing and conducting competence tests for teachers with respect to curriculum content at various levels. Teachers will be encouraged and incentivized to take regular competence tests as part of their training. The tests will be used for planning and making necessary capacity building interventions, not as part of performance management. It will be made continuously clear to teachers that there are no penalties or risks involved in their participation; rather, the test will be used in order to fulfil felt needs and plan training.

The incentives and benefits for teachers may include access to resources, and invitations to participate in events, conferences and study tours. A positive training and testing record may even play a role in promotion.

5.1.4.3. Assessment of STM

In terms of learning that can lead to innovation through STM, one of the fundamental concepts underpinning this is ensuring aligned assessment that addresses standards and mitigates problems through formative assessment, as well as building a system that encompasses theory and practice. To this end, there is a need to have formative assessment tools and guidelines – some of which are being developed by the national assessment and examination agency (for all subjects). There is also a need to develop a system that integrates the assessment of theoretical understanding and practical ability to make sure that students are capable of solving problems around them. Most of the implementation of practical work is teacher-based, where a teacher demonstrates practical sessions to students as part of the fulfilment of or support for understanding the concept. However, students must be the ones to perform the practical task, and the teacher's role is to help them as a facilitator. Hence, there is a need for a proportion of practical sessions to be allocated in the assessment of students.

5.1.4.4. Integrating technology, content and pedagogy in organizing STM

Integrating technology, content and pedagogy is proven to be essential for improved understanding of STME, and for enhancing innovation and creativity, which is necessary in order to fulfil Ethiopia's development endeavours. Hence there is a need to ensure the integration of technology, content and pedagogy for advancing STM. These include:

- Integrating technology, content and pedagogy into teacher preparation.
- Making this part of CPD in schools.

5.2. IMPROVING STM RESOURCES

5.2.1. The Function of Resources in Improving STME

The importance of resources in improving STME is indisputable. Research on school effects has generally shown that there is a modest relationship between educational resources and student learning. Hence resources have an impact on the quality of STM teaching and learning. While there is evidence to support this, it is tempting to overstate the significance of STM resources and their ability to independently achieve improvements in student outcomes.

The World Bank points out that "Overwhelming evidence shows that expansions on the input side, such as simple physical expansion of the educational facilities and increased spending per student, generally do not seem to lead to substantial increases in children's competencies and learning achievement (…) Simply providing generally increased resources or resources along the lines commonly suggested, such as reducing class sizes or across-the-board increases in teacher salaries, is unlikely to lead to substantial changes in student performance" (World Bank, 2007). However, the same report underlines that some investments, such as minimal levels of key resources, are valuable in promoting student learning. This strategic policy for STM accepts the need for adequate resources for each student and proper incentives for STM teachers.

As increased access to education is a recent phenomenon in Ethiopia, a shortage of competent and affordable STM teaching and learning materials is a common challenge across many schools, especially in remote and rural areas and across disadvantaged regional states. It is also essential to assess whether materials for certain topics are included in the curriculum. More effort, however, is needed to ensure that teachers can identify, access and use locally available materials effectively. There is support for basic resources such as quality lesson plans to assist teachers in planning what materials to use and how to use them. There is much evidence to support the fact that achievement is greatly facilitated when every student has a competent textbook and access to the equipment needed for the study of STM. Where it is not possible to provide a good textbook to every learner, there should be a competent and comprehensive set of worksheets.

ICT is a basic resource for STME and there are very few successful model education systems where teachers are not reliant on ICT as a basic resource for planning, implementing and managing their daily practices.

STME poses special challenges in that it is especially resource and equipment intensive. STM subjects ideally require special teaching-learning spaces and have special needs in terms of safety and resource management. This notwithstanding, there are successful international experiences/examples of the use of micro and small-scale kits that have proved to be cost-effective and to stimulate achievement in these subjects. There are also opportunities for sharing resources and using mobile resources that must be explored to ensure that all schools have access to what is needed.

Two challenging issues will be experienced in this regard: firstly, the availability of funding to equip all schools with ICT across the country; and secondly, ensuring the proper storage, maintenance and use of ICT resources.

5.2.2. The Strategy for Improving STM Resources in Schools

The strategic policy for STM includes the following interventions with respect to STM resources for schools.

- **STM resource database**: The strategic policy will include the development of a comprehensive checklist of minimum STM resources needed at preschool, primary and secondary schools, during TVET and at the tertiary level for the successful implementation of the relevant curricula in STM subjects. Wherever it is difficult to apply this, minimum standards will be set at each level. An additional list will be compiled for STM subjects in special schools. These lists will be based on existing lists at the national and regional levels. Each school will be asked to update their status with respect to the list. A regional level plan to ensure that all schools have the minimum requirements will be drawn up and implemented.

- **ICT resources**: One of the school improvement program components of the ESDP-V is ICT. The objective is to provide ICT infrastructure, facilities and resources to support teaching and learning and student development that can offer them the skills to work in an increasingly digital environment. It is believed that subsequent education programs will build on this. This strategic policy document therefore supports the initiation of the teacher/school laptop program to be fully realized by 2025**.** The strategic policy will seek to improve the level of ICT resources and usage in schools, to support the actions planned in the ESDP-V and much more. The government project aims to provide laptops for every school (and possibly for every STM teacher), along with adequate training and monitoring. The objective is to improve digital literacy to the extent that schools, teachers and students are able and willing to make use of email, internet, software and other digital education resources for STME. This can be achieved through the collaboration of the MoE with its development partners.

- **Small-scale equipment**: The strategic policy advocates the distribution to schools of micro science kits or other small-scale resources, rather than the provision of conventional large-scale facilities and laboratories. The CSMASEE will review the situation in schools and then seek to provide such resources where needed.

- **Students with special needs**: The strategic policy must pay attention to the resource needs of students with special needs. A campaign to review and upgrade resources and facilities for these students will be conducted during the ESDP-V period for this purpose. This will be further strengthened in subsequent programs.

- **Textbooks and worksheets**: The strategic policy accepts the notion that each student must have a competent textbook for mathematics and science. For this reason, the strategy will seek to provide guidance on the selection of textbooks and to provide adequate textbooks to all schools. As part of the strategy, the MoE/CSMASEE will engage with materials developers and publishers to agree on the format and production approach of new textbooks. Provision of additional reference and support materials will also be given due emphasis.

- **Regional education bureaus and resource centres**: The strategic policy will develop a plan to ensure that all regional STM officials, and then subsequently woreda education departments, are provided with the basic resources needed to support schools. This includes resources such as kits and ICT. As part of fostering a culture of professionalism in STM, the strategy will seek to promote the sharing of resources and a culture of resource borrowing from central and other locally available sources. The intention is to upgrade and supply a stock of loaned STM equipment and resources at one or more teacher resource centres per regional state, which will be gradually expanded to the woreda level.

- **Renovation of laboratories and special rooms**: There are many schools in the country that have laboratories and other facilities that should be used for STME, but which need refurbishment and/or upgrading. This will include the issue of security and safety with respect to resource storage and use. For this purpose, the strategy will seek to address this issue and encourage support from the private and public sectors as well as development partners.

- **Establishment of STM centres:** STM centres are critically useful for offering out-of-school learning environments and are a means for dissemination through the involvement of the public at large and concerned stakeholders. This strategy targets the establishment of such centres at regional/city level. The effort of bringing on board municipalities, local administrations and other organizations such as industries, NGOs, etc. is essential.

- **Establishment of special learning centres for gifted students**: This strategy involves the establishment of such centres at the regional level. The objective is to recruit and educate gifted and outstanding students so that they can access special opportunities to nurture their research and innovation skills in STM. There exist currently a few centres in the country with a similar purpose, but scaling these up and establishing a centre for all regional states is part of this strategy.

5.3. IMPROVING STME MANAGEMENT

STME in Ethiopia requires restructuring, both from a content and an administrative perspective. Content-wise, a national framework for STME needs to be developed that encompasses the vertical and horizontal organization of STME subjects with respect to the development needs of the nation. The current Centre for Strengthening Mathematics and Science Education in Ethiopia (CSMASEE), which lacks coherence and uniformity across regions, needs to be restructured, with all of the powers vested in it clearly stipulated, and in a manner that empowers action. There is also a need for building a system that ensures the smooth functioning of all organs and stakeholders towards achieving their planned intentions.

5.3.1. Reviewing and Managing the STM Educational Environment

Establishing a workable and transparent system and structure is one of the key challenges facing any education system, as success or failure in this regard affects the quality and management of curriculum delivery. The STM strategic policy will aim to establish a mandated STME institution that will consistently update this strategy and manage its implementation.

It is impossible to improve the federal level STME structure in a sustainable and productive way without following contextual approaches at the regional and district levels. The regional level education bureau system and structure are inextricably linked to the woreda level education offices. A comprehensive system and structure will (should) be put in place for the effective realization of this strategy at all levels.

5.3.2. Strengthening and Capacitating the CSMASEE

Established at directorate level under the MoE, the CSMASEE is in charge of coordinating and moving forward issues of STME in the county. Looking at its organizational structure, the CSMASEE requires more mandate and decision making power for certain administrative and managerial issues. These include:

- Establishing a competent, accountable and transparent leadership and governance system for STME under the CSMASEE. (This could be achieved through establishing the CSMASEE as a separate institution with financial and managerial autonomy, which is nevertheless responsible to the MoE and which conducts regular review meetings, including with regional representatives, that continuously study, act and reflect upon improving STME.)

- Launching and enhancing collaborative agreements between the centre and universities, and creating and strengthening similar centres at the regional level.

- Allocating a separate budget for the regional level centres with which to run their own specific programs.

For the strategic plan to achieve its overarching objectives, a strong and mandated institution at different levels is required.

Though there is a need to strengthen and capacitate the CSMASEE, the execution of the policy pillars and the enhancement of STME lies in cooperation efforts between all of the directorates and offices in the MoE, as well as with other stakeholders outside of the ministry. Thus the outlined policy strategy, as a continuation of what has been carried out previously by different sections and directorates of the MoE and other stakeholders, requires joint efforts to supplement or augment STME activities in order to include all relevant documents and teams that have a direct impact on the process. These institutions therefore have a role to play, in either setting new curricula or revising the existing ones, outlining pedagogical strategies that match the new curricula, training teachers to deliver the newer curricula, training teachers in pedagogical style, providing resources to implement action plans, etc. Some of the collaborating directorates, institutions and line ministries include:

- Curriculum Development & Implementation Directorate
- Teachers & Education Leaders Development Directorate
- Educational ICT Centre
- Special Support & Inclusive Education Directorate
- Planning, Resource Mobilization and Education Management Information Systems Directorate
- Procurement & Material Management Directorate
- Finance Administration Directorate
- Technology Capability, Accumulation & Transfer Directorate

Moreover, if the strategic policy is to affect the curriculum, pedagogy and assessment of STME at all levels, there is a need for strategic alignment (with regard to what type of national assessment to develop, where to place particular students within higher institutions, how to monitor quality in a sustained manner, etc.) with the following agencies and centres:

- National Educational Assessment and Examination Agency
- Education Training, Quality Assurance & Accreditation Agency
- Education Strategic Centre

5.3.3. Learning Culture Campaign

Establishing system and structure is very important, but making this happen takes a great deal of time, energy and budget. Campaigning is important and could sometimes be considered an element of a system or structure. Accordingly, a campaign will be launched in all schools to encourage teachers to adopt a strong STM learning culture. The campaign will strive to get teachers to increase the amount of writing and reading that is done as part of daily teaching and learning. It will also encourage and support teachers in giving and engaging in regular activity that is checked and reviewed. Involving the public through the establishment of centres for STM, museums, science days, conferences, etc. is considered part of the learning culture campaign.

5.3.4. School STM Targets

The effectiveness of this strategy depends on its accessibility to and impact on schools. The strategy will aim to encourage schools to set and achieve STM targets for each grade level. A range of incentives will be offered to schools that achieve their targets or which can show evidence of efforts to achieve them. The targets will initially be based on a feasible improvement of each school's current level of achievement. The second phase will be based on the school achieving a minimum percentage pass rate. The incentives will be non-financial and will include official recognition through an annual awards scheme. Schools will be invited to participate and will apply for this. Applying schools will receive initial benefits. A programme of support will be developed to assist schools to participate in the programme.

The strategy will also set standards of excellence that schools can aim to achieve in order to be recognized as ‘schools of STM excellence’. Similar levels will be set to be recognized as a ‘school of high achievement in STM’. This will be done at woreda, zone and regional levels.

5.3.5. Crosscutting Issues on STM

As STM is a priority of the government, and there are sectors working on STM such as the MoE and the MoST, there is a need among all stakeholders to work in alignment so as not to duplicate efforts. Hence this strategic policy aspires to the establishment of a board that will oversee the strategic interventions and lead the overall functioning of the strategic policy.

5.3.6. Monitoring and Evaluation of STM Functioning

The effectiveness of this strategy depends on its smooth functioning and the achievement of stated targets/goals. The strategy aims to encourage the installation and execution of regular monitoring and evaluation systems at all levels, from schools up to the central level. The monitoring and evaluation activities aim to strengthen capacities and mitigate problems, with the view of achieving the mission and vision of this strategic policy and realizing the achievement of the country’s development endeavours.

6. POLICY IMPLEMENTATION AND PRINCIPLES

Making STME strategic policy a reality and continually improving it requires enormous financial, institutional and technical efforts. In the drive to meet the country's overarching goal of becoming a middle-income country, implementing this strategic policy is not only essential, but furthermore all efforts and resources are required. Among others, the MoE will play a leadership role, with the active involvement of other stakeholders.

The primary task for this is the establishment of a clear and effective STME governance structure, developing a specific implementation framework and creating a common understanding among actors.

Implementation of the strategic policy will be based on principles that can ensure the effectiveness and efficiency of the national STME. The major principles include:

a) The MoE will take on a leadership role, including in the overall capacity building process.
b) The integration of STME activities with other socio-economic activities will be given due consideration.
c) By strengthening the public-private partnership, the overall implementation process will increase the effectiveness and performance of tasks.
d) Resources will be utilized in a transparent and accountable manner.
e) Working with development partners will promote the effectiveness of policy implementation.

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ANNEX I: LIST OF INDIVIDUALS CONSULTED AND INTERVIEWED

1. Dr. Sileshi Yitbarek: Assistant Professor, Science Education, Kotobe University College and Executive Member of Chemical Society of Ethiopia
2. Mr. Derese Abate: Physics and Pedagogy Lecturer, PhD Candidate in Science Education, Kotobe University College
3. Mr. Antenh Tefera: PhD Candidate in Science Education, AAU
4. Mr. Gizachew; Lecturer at Kotebe University College and PhD Candidate in Science and Mathematics Education, AAU
5. Mr. Iseyas W/Tensay: Lecturer at Adigrat University and PhD Candidate in Science and Mathematics Education, AAU
6. Mr. Desta Geneme: PhD Candidate in Science Education, AAU
7. Mr. Bude Wako: Lecturer at Wachemo University and PhD Candidate in Science Education, AAU
8. 9 Male and 2 Female participants from CSMASEE including Mr. Belayneh:

a.	Tigist Getahun	Laboratory	tigist3866@gmail.com
b.	Etanesh Mekonen	Biologist	slometiti@yahoo.com
c.	Danial Demesa	Mathematics	uliya-16@yahoo.com
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g.	Zelekew Teshom	Laboratory	zelelew.teshome@gmail.com
h.	Hailu Genebe	Laboratory	ለበበለ2001@gmail.com
i.	Mekonet Addisu	Biologist	mackpath@gmail.com
j.	Nesibu Mengestu	Chemist	nesibu2000@yahoo.com
k.	Ermias Chfamo	Mathematics	ermias855@gmail.com
l.	Belayneh Tefera	Head	bellg-tef@yahoo.com

9. Four male and 1 female experts from Oromiya Regional State Bureau of Education:
    a. Mr. Alemu Gessesse, SMASSE Coordinator
    b. Dereje Girma, mathematics expert
    c. Mossissa Dejene, biology expert
    d. Alemtsehay, chemistry expert
    e. Tilahun, curriculum expert

10. Four male experts from Addis Ababa Bureau of Education:
    a. Mr. Mekonnen, chemistry expert
    b. Mr. Berhanu, biology expert
    c. Mr. Amanue, TDP coordinator
    d. Mr. Getachew, physics expert
    e. Mr. Degu, TDP expert

11. Deputy principal and one teacher from each stream (biology, chemistry, mathematics, physics and ICT) at Kokebe Tsebah Secondary School
12. Members from Ministry of Science and Technology
13. Mr. Zenebe Deneke, Manager Aster Nega Publisher
14. Mr. Mulugeta Naizghi, President Mathematical Association of Ethiopia
15. Dr. Tetemke Mehari, veteran teacher in chemistry
16. Mr. Befekadu Zeleke, Executive Member of Teachers' Association
17. Mr. Ataklti Araya, Lecturer at Mekele University and PhD candidate in mathematics
18. Mr. Wolde, Lecturer at Arbaminch College of Teacher Education
19. Mr. Hussien Indris, Lecturer at Dessie College of Teacher Education
20. Mr. Getachew, Lecturer Gondar College of Teacher Education
21. Dr. Mulugeta W/Michael, Assistant Professor at Diredawa University
22. Dr. Tesfu Belachew, Assistant Professor at Medawelabu University
23. Dr. Tadele Ejigu, Assistant Professor at Bahirdar University
24. Mr. Abraha Tesfay, Lecturer at Mekelle University
25. Mr. Tsegaye Mekonnen, teacher at Saint Mary Cathedral Secondary School
26. Mr. Tsedeke, Lecturer at Hossaena College of Teacher Education
27. Dr Hilluf Reddu, Assistant Professor Aksum University
28. Mr. Mengesha Belayneh, D/Director Meskaye Hizunan Secondary School
29. Dr. Mekbib Alemu, Assistant Professor Addis Ababa University

ANNEX II: LIST OF VALIDATION WORKSHOP PARTICIPANTS

Table 5: List of Validation Workshop Participants

No.	Name	Institution
1.	Habtamu Gebre	Ministry of Education
2.	Fekade Dessalegn	Ministry of Education
3.	Ahmend Seid	Ministry of Education
4.	Dr. Sileshi Yitbarek	Kotebe University College
5.	Getahun Getachew	Addis Ababa Bureau of Education
6.	Girma Mengistu	Addis Ababa Bureau of Education
7.	Eskinder Lakew	Ministry of Education
8.	Yibeltal Solomon	Ministry of Education
9.	Mulugeta G/Kiros	Abbi Addi College of Teacher Education
10.	Fekadu Alle	CEICT
11.	Wolde Belachew	Addis Ababa University
12.	Yenealem Ayalew	Addis Ababa University
13.	Eyasu Gemechu	Addis Ababa University
14.	Mulugeta Naizghi	Mathematical Association of Ethiopia
15.	Befekadu G/Tasdik	USAID
16.	Dr Tetemke Mehari	Chemical Society of Ethiopia
17.	Melaku Berhe	AASTU
18.	H/yesus Sileshi	AASTU
19.	Muluneh Tekleberhan	Addis Ababa Bureau of Education
20.	Weldehana Lobago	Addis Ababa Bureau of Education
21.	Sisay Bezabih	Ministry of Education
22.	Melkamu Dabba	Ministry of Education
23.	Prof. Shibru Tedla	Ethiopian Academy of Science
24.	Prof. Masresha Fetene	Ethiopian Academy of Science
25.	Sisay Mulugeta	Ministry of Education
26.	Abraham Kumsa	Addis Ababa University
27.	Habtamu Gerba	Ministry of Education
28.	Fekadu Dessalegn	Ministry of Education
29.	Dr. Gemechis Fille	Jimma University
30.	Dr. Gebrekidan Mebrahtu	Mekelle University
31.	Melaku Takele	Jimma
32.	Dr. Eshetu Hailiye	Bahirdar
33.	Dawed Yimer	Gondar
34.	Tilahun Bimerew	Gondar
35.	Bokki Tollan	Assela
36.	Kebede Alemu	Debre Berhan
37.	Daniel Assefa	Dilla
38.	Kassahun Ture	Balle
39.	G/Tsadik Gidey	Arbaminch
40.	Diddi Assefa	Ambo
41.	Melkamu Biyana	Wollega

42.	Dr. Tesfahun Kebede	Harremaya
43.	Negussie Arefaine	Jigjiga
44.	Dr. Abebe Tedla	Debre Berhan
45.	Mesele Molla	Wolaita Soddo
46.	Mulugeta G/Kiros	Mekelle
47.	Dr. Abebe Amaha	Adama
48.	Dr. Eshetu Bekele	Adama
49.	Dr. Legesse Lemecha	Adama
50.	Dr. Abebe Belay	Adama
51.	Demis Shimelis	Hawassa
52.	Belayneh Tefera	Ministry of Education
53.	Hiroyuki Tanaka	JICA
54.	Miyazaki Takeshi	Ministry of Education/ JICA
55.	Dr Tilaye Gete	Ministry of Education
56.	Dr Kassa Michael	Addis Ababa University
57.	Dr Mulugeta Atnafu	Addis Ababa University
58.	Dr. Margarethe	Education Strategy Center