**Original Article**

# Trends and Orientations in Science and Mathematics Education in Ethiopia

*Yenealem Ayalew Degu*

*College of Science and Mathematics Education, Kotebe University of Education, Ethiopia*
*Email: yenealem.ayalew@kue.edu.et*

**Abstract**

The historical and philosophical foundation of science and mathematics education (SME) is not well documented in the Ethiopian context. The writing of this article was initiated from unclosing how the field is conceptualized and enacted. Indeed, there have been various initiatives on STEM (science, technology, engineering, and mathematics). The implication is that STEM education is an integration of the fields including science education and mathematics education. Yet, to what extent is the inclusion? Again, is STEM part of science and mathematics education? In order to answer such questions, accessible data on events, project activities and educational studies pertinent to the subject were collected and reviewed. In this regard, email correspondences and focus group discussions were among the tools. Then, the analyses brought two underlying perspectives: the educational/training practices in subjects and the field as a domain of knowledge and research. In the one hand, issues of curriculum and policy, teaching and learning, textbook research and development, lesson study, context, and teacher training were found prioritized. On the other hand, Science/Mathematics Education, as a field of study and practice, has been evolving in four hubs. The historical foundations, learned experiences and the contemporary issues imply to the existence of different points of views. It is found that STEM education and Science/Mathematics Education are not connected. Thus, there is a need to boost the field as a valuable foundation for viable development.

Key Terms: Mathematics Education, Science Education, STEM, Teacher Education

## 1. Introduction

The concept of Science and/or Mathematics Education has been addressed differently by academicians and political leaders, internationally. Globally, there are various initiatives in line with SME including: business firms, non-for-profit organizations, foundations, research centers, consortiums, conference series, reputable journals, and programs. For instance, the *Delaware*

*Foundation for Science and Mathematics Education*, in USA, was formed in 1995, embraces activities of STEM fields, STEM education, and STEM careers. The *Center for Mathematics and Science Education* at California State University, USA, was founded in 1993, is a non-profit organization serving as a liaison between the University, colleges, K-12 schools, and the business community in the areas of mathematics and science education. Besides, *Centre for the Advancement of Science and Mathematics Education* in South Africa, is a dynamic force dedicated to revolutionizing STEM. From these cases, we can see that STEM is included in Science and Mathematics Education.

In Ethiopia, Science and Mathematics have been included as basic subjects in school curricula. Improving instruction of the subjects is regarded as a priority for developing countries (Bethell, 2016; Engida & Areaya, 2008; MoSHE, 2019). The issue has been an area of interest of the global community. It is possible to consider people who involve in, events, programs, publications and career opportunities as fundamental aspects of discussion (Ayalew, 2019). A number of strategic activities (Belay *et al*, 2016); MoSHE, 2019, 2020) have been initiated with the aim of improving the quality of SME (Ahmed *et al*, 2019). Politicians, education leaders and policymakers used to call for a new emphasis on the fields of Science, Technology, Mathematics and Engineering in the nation's schools, from primary school through to postsecondary education (Belay *et al*, 2016). As a result, there was a revision of pre-service teacher education programs and a provision of new in-service training programs for science and mathematics teachers (Ahmed *et al*, 2019).

From the above two paragraphs, it can be implied that STEM education is an integration of the fields including science education and mathematics education. Yet, to what extent is the inclusion? Again, is STEM part of science and mathematics education?

## 2. Methods

In this study, a qualitative content analysis was employed whereby necessary data were gathered mainly from 24 potential informants (primary sources) via telephone call, email correspondence and focus group discussions. Besides, available or accessible documents on the matter were reviewed. The results were presented in detail and then exhaustive discussions were made with emerging themes. Thus, concluding remarks were noted on the delivery approaches of the field of study, the underling perspectives and points of views, existing supplementary roles, and

complementary actions. Subsequently, a forward looking was pointed out in relation to integrated approach and differentiated tracks of studies in the field.

## 3. Results

### 3.1. Commencement of Science/Mathematics Education in Ethiopia

In Ethiopia, students' performances in science and mathematics subjects have remained below the basic level of proficiency (Getahun, 2022). Since the historical development of science education system was not explored (Sbhatu, 2021), its status of the as a field of research, practice and scientific domain is not yet organized. Indeed, the title "Science and Mathematics Education in Ethiopia" was addressed in 2008. The current study is intended to disclose an updated report on SME in Ethiopia with a particular reference to the past twenty years. Towards this end, I surveyed diverse events, publications, project works, activities of organizational units or established centers and developed strategies which I think are pertinent to improvement. Science/Mathematics and education/pedagogy co-exist; yet, the idea of "Science Education" "Mathematics education" as a domain of knowledge is a new experience in Ethiopia. The blending of Mathematics and Education has been operational in teacher education and other programs. For instance, Bahir Dar University (BDU) had been running Pedagogical Science major concentration area along with Mathematics/English/Geography/Amharic-language minor (and major later in 2001) fields of studies. The main professional goal of the program was producing competent teacher educators. The curricula for both primary and secondary teachers' education emphasize the need for strong content knowledge and professional pedagogical skills (Ahmed *et al*, 2019). Facilitations of undergraduate, Master's and doctoral programs pertinent to the field "mathematics education" have two decades history in BDU.

### 3.2. STEM – Science, Technology, Engineering and Mathematics

Basically, STEM is an educational initiative with integrative approach to help students gain the ability to think critically, solve complex problems, and drive advancements in science and technology (MoSHE, 2019). Such a holistic integration indicates awareness to the possibility of being a part of a global society in these turbulent times (Kobayashi, 2019). "Critical thinking", "problem solving" and "project-based learning" could be labeled as contemporary pedagogical approaches. Who is going to maintain the interdisciplinary nature and techniques and methods of

integration? On the other hand, "STEM center" is specialized learning facility that offers hands-on experience to local area where students voluntarily and eagerly enroll into various age-appropriate programs offered, at no tuition fee for the students (MoSHE, 2019). It is a site that provides quality professional development activities and resources to support STEM Education.

In this regard, teachers are target groups. A lesson or unit in a STEM class is typically based around finding a solution to a real-world problem and tends to emphasize project-based learning that means, STEM is an interdisciplinary approach to learning where academic concepts are coupled with real-world lessons. By exposing students to STEM and giving them opportunities to explore STEM-related concepts, they may develop a passion for innovation and, hopefully, pursue a job in a STEM field. A pioneering activity at BDU is *STEM* center which incorporates summer outreach program for talented students, Math Camp programs and Science Shared Campus program. Outreach program for talented students was a two years project financed by Mr. Mark Gelfand aiming to maximize the number of science and technology students with a motto" inside every child there is a scientist".

> *…The training was hands-on-practical laboratory work and conducted in laboratories found in the university compound. The training program included the following core school subjects such as: Physics, Chemistry, Biology, Mathematics, ICT, Electronics, Technical Drawing and English. In addition, extracurricular activities, and educational Trips were also included in the program. A "team teaching" mode was followed which included 1 University instructor, 1 Laboratory Technician, and 1 School Teacher in an instruction. 25 students placed in one class for 3 hrs laboratory work. (Email correspondence with informant 2, by 25$^{th}$ Dec. 2022)*

The project was also aimed at establishing and supporting Science and Technology clubs in schools aimed at attracting and supporting more talented students to involve in the summer training programs and project works. BDU has been also offering annual Math Camp program for interested and talented students. The following narrative conveys its intent.

> *Math camp program was started in July, 2012 in department of mathematics, BDU. The camp takes place June to July in the main campus and stays for two weeks. The aim is to make Mathematics a real fun and pressure-free place. It is not merely a 'Math teaching' session, but a training program that includes computer programming, computer graphics, physical exercises, socialize and leadership development, etc. Students are housed in a dormitory. Students participate in recreational activities (at the dorms, athletic fields, classrooms, etc.). The University runs annual Girl's STEM camp program for talented girl students from grade nine to twelve. STEM Girl's Camp program was started in January, 2014 in STEM Center. The camp takes place during*

> *the semester break, in the main campus of BDU and stays for two weeks. (Email correspondence with informant 12, by 25th Dec. 2022)*

Currently, there are several STEM centers in Ethiopia. It is possible to consider STEM education as essential for learners moving beyond memorizing facts and formulae, and ensure that they gain an understanding of the principles of science and mathematics that underlie so much of contemporary engineering practice and technological development (Ahmed *et al*, 2019). On the other hand, *Science Shared Campus* aims at providing laboratory-based training by university instructors on STEM related school subjects and English language, where other school subjects are taught by the nearby governmental school teachers. For instance, Bahir Dar University and Kotebe University of Education, and Hawassa University run such a program.

### 3.3. BDU - NORHED

BDU has been implementing NORHED [Norwegian Programme for Capacity Development in Higher Education and Research for Development] project in two phases. The first one was: "Advancing Quality in Education in the Primary and Lower Secondary Schools in Ethiopia and South Sudan (August 2016 – August 2021)". The second phase: "Enhancing the Quality of Science and Mathematics Education in Ethiopia (2021-2026). The project has components programs: research, postgraduate programs, staff capacity building and outreach. So far two international conferences on SME were held. The first happened during 23-24 October, 2019 with theme of *Making Science and Mathematics Teaching and Learning Impactful.* The second one was held on Dec. 29-30, 2022 with a theme of *Science and Mathematics Teaching, Learning and Assessment: Lessons from Theory and Practice*. Prior to these events, the College of Science at BDU had hosted two Seminars/conferences (in 2012, 2015) on Statistics, Mathematics and Science education. Thus, there were totally four conferences there. Besides:

> *"Center for Studies in Teaching and Learning of Science and Mathematics" would be established sooner (interview with informant 3, by 30th Dec. 2022).*

This is a great deed as compared to other universities in the country. Although related programs are hosted at both colleges of the university, the promise of institutionalization of BDU-NORHED project would solve the polarization. All in all, BDU is the birth place of Science and Mathematics Education. Yet, the university is late to establish an organizational unit.

### 3.4. Initiatives at the Ministry of Education

In 2004, secondary schools were using Satellite or Plasma Television as a medium or tool. The use of computer animations and experiments in demonstration sessions were interesting. The underlying intention was to give all secondary schools in the nation opportunities for uniform and standardized instruction consistent with the curriculum. There was a prior concern that SME had been reduced to eyes-on and ears-on learning at the expense of hands-on learning (Engida & Solomon, 2008). This could potentially be alleviated by aligning the curricula for teacher training program with school curricula and focusing on topics that can promote scientific reasoning, as well as focusing instruction on authentic practices, can contribute to transforming prospective teachers' scientific reasoning ability (Getahun, 2022). It is important to address relationships between conceptions within the SME and conceptions and ideas from other fields (Skovsmose, 2009).

### 3.5. JICA's Education Sector Development Projects

Japan International cooperation Agency (JICA) in Ethiopia is primarily working on four areas of development: (*i*) agriculture and rural development, (*ii*) industrial promotion, (*iii*) infrastructure development, and (*iv*) Education. Among the projects conducted in Ethiopia was JICA's contribution on: Strengthening Mathematics and Science Education in Ethiopia [SMASEE] (2011-2014), Capacity Development for Improving Learning Achievement in Mathematics and Science Education [LAMS] (2015-2017), and Mathematical Understanding for Science and Technology [MUST] (2019-2023). LAMS aimed to reform Ethiopia's educational assessment systems by strengthening the capacity of officials or five working groups of Mathematics, Biology, Chemistry, Physics, and Assessment and Evaluation (JICA, 2017).

> *By implementing project documents such as SMASEE and LAMS, efforts have been made to improve the learning outcome just by preparing Item pool and work book for selected grade levels. However, there were some of the challenges. For instance, same structure of MSIC [Mathematics and Science Improvement Center] was not organized/established in all regions. Besides, there was lack of attention given to mathematics and Science Education by [different] stakeholders. Scaling up of the results of the training was not effective at the desired level. School and cluster-based trainings were not effective and efficient as expected. (Email correspondence with informant 14, by 21st Dec. 2022).*

JICA's contribution to the education sector development of Ethiopia has been a lot (Belay *et al*, 2016). The practical activities were inclusive of syllabus and textbooks developments, the adaptation of lesson study and making assessment meaningful.

### 3.6. Mathematics and Science Improvement Center

Following the introduction of SMASEE in Ethiopia, the MoE established a unit MSIC (Mathematics and Science Improvement Center) which was mandated to the improvement of the teaching and learning of Mathematics and Science Ethiopia. For full functionality of the unit, there have been assigned or appointed leaders and coordinators. The Center/Directorate/Desk belongs to the education development sector. Yet, the MSIC was not upgraded as it was proposed. Rather, it is re-organized under teacher and educational leader development office. Below is a report from a focus group discussion (FGD) member.

> *The Center or Desk has been organizing Science Fairs in Ethiopia. Regions have been fundamentally coordinating the selection of candidates. Then, in collaboration with different stakeholders, we make national level (FGD, informant 5, by 19th Dec. 2022).*

The center (currently desk) has been reaching out 33,000+ trainees, National science fairs, baseline researches (e.g. Status of Laboratory Study Report) and National Conferences on STE(A)M (in 2012 and 2021).

> *Currently, the STEAM [Science, Technology, Engineering, Art and Mathematics] desk is accountable for Teachers and Educational Leaders Development Chief Executive Office. (FGD, informant 5, by 19th Dec. 2022).*

Another attempt by the MoE was the formulation of Mathematics, Science and Technology education policy. The rationales were outlined as follows. There were weaknesses of the status and factors that hindered the attainment of objectives in the fields (Belay *et al*, 2016). It is usually heard that mathematics and science teachers had knowledge and skills gaps in terms of lesson planning, active learning methods, and assessment skills

### 3.7. Department of Science and Mathematics Education (SMED) at AAU

In 2003, Teacher Education System Overhaul (TESO) was planned and established as a nerve center for Teacher Education reform (Negasi, 2015). It has worked tremendously to fit a critical gap in the education system.

> *The Academic Year 2003/04 was a turning point in the history of the Faculty of Education (now College of Education and Behavioral Studies) at Addis Ababa University (AAU). As per the national Teacher Education scheme, the faculty of education restructured itself to house eight more new Departments. Four of these (Department of Biology Education, Chemistry Education, Physics Education, and Mathematics Education) were headed by an Assistant Dean for SME stream (at Arat Kilo Campus). The restructuring was an opportunity for development in the history of teacher education. It mainly creates a fertile*

> *ground for Mathematics and Science teacher educators to appropriately integrate their subject area knowledge with modern pedagogical skills the teaching profession demands. This restructuring created and allowed the stream for Department of Science and Mathematics Education (SMED) to address the educational function of the science and mathematics fields. There were four departments under the SMED unit running both preservice and in-service undergraduate teacher education. (Email Conversation with informant 6, by 15th Dec. 2022)*

The four departments under the SMED unit running both preservice and in-service undergraduate teacher education were: Department of Mathematics Education, Department of Physics Education, Department of Chemistry Education, and Department of Biology Education. Besides, Sport Science Education has been attached to SMED. On the other hand, TESO had also been implemented at other universities with Faculty of Education. By then, the most pronounced words of the TESO program were "B.Ed" and "Practicum".

> *In 2005, the SMED unit, in collaboration with UNESCO [United Nations Educational, Scientific and Cultural Organization] IICBA [International Institute for Capacity Building in Africa], introduced a Master's program (M.A in teaching Science and Mathematics). Science & Mathematics Education is a potentially rich and virgin area of research, and much more is expected of educators to pursue academic excellence in this regard. In the 2007/08 Academic Year, the SMED stream launched regular post-graduate programs (M. Ed) in Mathematics Education and Physics Education. In 2009, the SMED unit launched a Ph.D. program in SME which is the first of its kind in Ethiopia. The program aimed at offering a terminal (Ph.D.) degree in the areas of Science & Mathematics Education in four tracks: Biology Education, Chemistry Education, Physics Education, and Mathematics Education. This program is primarily, but not exclusively, for those who have M.Ed or M.Sc degree in Biology, Chemistry, Physics, or Mathematics and have been giving services in Universities and higher learning institutions. It also considers other candidates who have been teaching and researching in other private and public higher learning institutes, consultancy organizations, and government and non-government organizations. However, the road was not smooth; there were lots of resistance and denial of the field of SMED. (Email Conversation with informant 6, by 15th Dec. 2022)*

IICBA advocates "Strengthening Teacher Development in Africa" has supported the establishment of MA in SME in 2004. The project served as a pilot program and the first full-fledged M.Ed program was launched in 2007. Then, a benchmark publication on the field of discussion was "Science and Mathematics Education in Ethiopia: Policy, Curriculum and Implementation, 2008". Currently, the SMED department offers Masters, D.Ed., and Ph.D. Degrees in different tracks. The programs are designed to equip graduates with the knowledge, attitudes, and skills necessary for working at colleges, universities, and research institutions in today's dynamic world of work. Starting from scratch, currently, the SMED department at the College of Education and Behavioral

Studies produced significant number of suppers performing graduates in Master's degree and many in Ph.D. who are teaching and researching at different public universities in Ethiopia. The SMED department also has a well-experienced staff, including two Professors.

> *Generally, due to intense individual and teamwork and strong dedication and struggle, SME has matured in Ethiopia. Four departments of BioEd, ChEd, MaEd, and PhyEd were full-fledged departments until the end of 2003 E.C. Later, [the associate dean office] was rearranged as a SMED Program [and sustained] unit until 2005 E.C. Afterwards, it [unit] grew and was acknowledged as a full-fledged department. (Email correspondence with informant 7, by 24$^{th}$ Dec. 2022).*

SME at the College of Education and Behavioral Studies has passed through different statuses: Associate Dean for Department of Science and Mathematics Education, Natural Science Program Unit, and Department of Science and Mathematics Education.

> *Currently, there are 15 academic staff members in the department and out of these are 2 professors; 5 associate professors; and 6 assistant professors. They are actively involved in the teaching-learning, research and dissemination and community service, some of the achievements are: the staff members publish more than 200 articles in reputable journals; the staff members participated in more than 6 thematic research projects, 7 individual research and 1 collaborative research with Durham University. The staff members are acknowledged by 2 university level research awards, 2 University level teaching awards, and 1 outstanding performance at national level. (Email Correspondence with informant 8, by 22th Dec. 2022).*

The above paragraphs imply that "Science and Mathematics Education" as field of study has a good foundation at AAU. A reputable "Friday Seminar/Lecture Series" can be considered as a brand whereby two (online) presentations per week are being delivered by the postgraduate students and invited guests to share their thoughts.

### 3.8. "Transforming the Pedagogy of STEM Subjects"

Usually, four subjects (Science, Technology, Engineering and Mathematics) are coined together as STEM. However, most educational studies in Ethiopia seem to focus on secondary Mathematics and Science. Yet, what is the difference between the concepts of STEM Education and STEM program?

> *STEM initiatives started as a way to promote education in these related areas so that students would be prepared to study STEM fields in colleges/Universities and pursue STEM-related careers. The first STEM center in Ethiopian is established in Foka Science Center which was financed by Mr. Mark Gelfand, an American Philanthropist to maximize the number of students in science, technology, engineering and mathematics*

> *with a motto" Inside every child is a scientist". Then, BDU STEM Incubation Center is then established through the support of Mr. Mark Gelfand. The major objective of the center is to provide hands on practical laboratory-based STEM education for school students and teachers. Students selected from summer outreach program are the major beneficiaries of the center. They can get unlimited library, internet, and laboratory accesses. Students' group and individual based project works are also supported by this center. In addition, it is used as a teaching and learning resources center, where, like audio and video files, books, laboratory manuals, learning/teaching software and standardized exam items. (Email Conversation with informant 12, by 25th Dec. 2022).*

It is shared via home page of BDU that the center is well equipped with necessary laboratory materials and functioning fully both in the whole academic year and Summer time. The center includes: a laboratory complex and an open-air technology park that will contain STEM based project works for further improvement and transfer of knowledge.

> *In July 15, 2012, BDU in collaboration with MoE hosted a National Conference on "Present and Future Direction of Science, Technology, Engineering and Mathematics (STEM) Education in Ethiopia." On the occasion, Outreach Program for Talented Students project were officially commenced. The conference was meant to brief participants about STEM education, to discuss strategies that would help to scale up STEM at country level. (Email correspondence with informant 12, by 25th Dec. 2022).*

Since Education is formal, non-formal, and informal type, such activities as STEM could enable potential stakeholders to think beyond the minimum learning competencies which are expected of students. However, studies continued to show that students' achievements are still low. Hence, there is a continued capacity building (training) Demand for Mathematics and Science Teachers. In this regard, the Education Bureau of Somali Regional State initiated such gap filling programs. Yet, the challenge is the mentors assigned for are not appreciated by the trainees.

> *There is a capacity building program for science and mathematics teachers in the region with the collaboration of JigJiga University. However, trainees are heard of complaining the assignment of former instructors in this new program. (Email correspondence with informant 17, by 25th Dec. 2022).*

The compliant is crucial in that a continuous professional development program has to be guided by mentors with appropriate experience. A study conducted at another region in Ethiopia showed that there is a low level of scientific reasoning ability among teacher educators, schoolteachers, and prospective teachers (Getahn, 2022). That in turn calls for trainers' professional profiles in knowledge, skill and attitude. Thus, it implies that SME is a full-fledged field of knowledge in its

own right. This might be realized when committed individuals and institutionalized units are there in the country. For instance,

> *The former SMASEE [Strengthening Mathematics and Science Education in Ethiopia] project was institutionalized into MSIC [Mathematics and Science Improvement Center]. It was commenced based on three regions (Addis Ababa, Amhara & Oromia) pilot training of 224 Trainers. Then, the regions began cascading. (FGD, informant 5, by 19th Dec. 2022).*

SMASEE was initiated by the kind support of the Government of Japan. It is clear that different countries dominated modern education in Ethiopia which in turn influenced policy and programs including curricula. This has made the relevance of reforms inadequately tailored to the country's development needs (Tadesse *et al*, 2022). Then, strengthening the STEM workforce can be realized by increasing the number of students who pursue a career in related fields as well as broadening STEM literacy (MoSHE, 2019).

> *SMASEE was proposed mainly in trainings formats. The trainings were facilitated by use of 24 modules corresponding prepared for [teachers of] different grade levels Mathematics, Physics, Chemistry and Biology subjects. (FGD, informant 9, by 19th Dec. 2022).*

It seems that the project was well planned from the very beginning. The following text could be additional reference.

> *The modules were developed based on teacher's knowledge limitations and skill gaps. Besides, documents are prepared for learning of animation. (FGD, informant 5, by 19th Dec. 2022).*

The programs or trainings had been implemented with a follow up and monitoring activities. The next text can be quoted here.

> *The project was led by a steering committee. A survey conducted on the implementation of the project showed its effectiveness. In other words, trained teachers were more effective than untrained ones. The center [MSIC] then facilitating the trainings of more than 33, 000 teachers and laboratory technicians. However, there were drawbacks… like… the local training might be fragmented. For instance, the 5 days long training could be finished in 3 days. (FGD, informant 9, by 19th Dec. 2022).*

As it has been narrated earlier, there have been some initiatives. However, system formation and cascading of programs are the limitations. For instance, there is no nation-wide hub for science and mathematics education. There is no center for the study at Regional or cluster level either. Below is an evidence of contribution of (Project for Capacity Development for Improving) Learning Achievement in Mathematics and Science Education (LAMP) in Ethiopia.

> *We [MSIC] have been collaboratively working with LAMP team members. After a baseline survey assessment for MUST was conducted, the project team members turn to curriculum and textbook development process. And, thus, our attachment with MUST people has temporarily interrupted (FGD, informant 5, 19th Dec. 2022).*

Instructional interventions or (supplementary) teaching-learning supports are supposed to fill observed gaps. Laboratory technicians are needed to push the classroom bounded theoretical content (knowledge) into practical. "Science" education would be meaningful when it has experimentation.

> *I joined the former MSIC as a Laboratory Technician. I am currently working as a National [Teacher] trainer. The current STEAM desk is organized by a composition of one Head and two trainers plus one Technical Assistant in the respective fields. FGD, informant 10, 19th Dec. 2022).*

Most laboratories in Ethiopian secondary schools are short of qualified and committed science teachers (Engida & Areaya, 2008). This is not yet solved. The general name "Technician" is not only laboratory experts but also for skill learning scenarios. For example, the plasma television demands technicians.

> *… with regard to Technical Assistants for secondary school education, Ambo University had been delivering undergraduate courses. … Schools demand skilled technicians. However, there are [almost] no professional technical assistants in schools. Even the available technical assistants are not getting fair treatments. Equipment and chemicals are managed by a store keeper. On the other hand, the teacher is expected to handle laboratory works. (FGD, informant 11, by 19th Dec. 2022)*

Of course, there is an argument on whether teachers themselves have to be skilled with necessary technical requirements of the subject they are teaching of or not. On the other hand, the function of instructional television as medium of instruction or (supplementary) teaching-learning aid was supposed to fill the gap (Engida & Areaya, 2008). Although the STEM programs are being advocated here and there, there are no life time specialists in the area.

> *The STEAM desk is not fully organized with professionals. (FGD, Des'a, 19th Dec. 2022).*

So, the alignment or assignment of sufficient number of individuals in line with to a program designed.

### 3.9. Teachers and Educational Leaders Development

In the history of teachers' training, the introduction of TESO and establishment of Centers of Excellences in Teachers and Educational leaders' development have played a great role on putting *Teacher Education* as a domain of study. An issue in teacher education is the debate regarding the best way to educate teachers (Negasi, 2015). There had been a time for TESO.

> *In 2008-2009, Haramaya University started M.Ed programs in Biology, Chemistry, Mathematics and Physics subjects. Although the regular program was interrupted, we are implementing MoE's curriculum for summer-in-summer modalities. (Telephone conversation with informant 20, by 25th Dec. 2022).*

Once again, a few years ago, five centers of Excellences in Teacher and Educational Leaders Development were established at Addis Ababa, Bahir Dar, Jimma, Hawassa and Mekelle Universities. Then, there came a total shift to installation of "applied" science programs. The preparation of teachers and educational leaders or school principals was framed by BSc/BA plus PGDT [postgraduate diploma in teaching]. Currently, there are two alternative approaches to teacher education: TESO and Subject Specialist plus PGDT. The first was endorsed in trying to address the serious problems present in the education system. The Ethiopian government has called for a complete TESO (Negasi, 2015).

> *… after the collapse of TESO, there was a total shift in to Science. The PhD program was paused and was in a position to be discontinued. Even the university [AAU] couldn't handle the survival. Thanks to the commitment of individuals, the then Minister of Education and Prime Minister were informed about the international experience and the relevance of "Science and mathematics Education". Again, with the kind collaboration of international partners and using the competency of first batch PhD candidates as evidence, the tertiary degree program was re-commencing. (Interview with informant 7, by 20th Dec. 2022)*

Science and mathematics have a particular reference to Modernity, as the Scientific Revolution provides a portal to the modern worldview. But as already mentioned, Modernity also means colonization, suppression and exploitation. And this includes colonization of ways of thinking and doing. Such an insight also forms part of any critical professionalism within the domain (Skovsmose, 2009). On the other hand, most [Science and Mathematics] teacher educators at Colleges are subject specialists with very little or no pedagogical content knowledge (Ahmed *et al*, 2019). They could be products of an old educational culture that considered subject mastery to be the main foundation of quality learning and teaching. Thus, there is a need to introduce specific

teacher educator training programs that can better provide teacher educators with pedagogical content knowledge [PCK] (Getahun, 2022). The PCK has been a guiding model in the aforementioned *teacher education* programs.

### 3.10. A College of Science and Mathematics Education at KUE

Following the Government's direction on differentiating the Higher Education Institutes, Kotebe University of Education (KUE) has revised its structure and programs. The College of Science & Mathematics Education – Kotebe University of Education constitutes the Department of Biology Education, Department of Chemistry Education, Department of Information Technology Education, Department of Mathematics Education, and Department of Physics Education. The college trains future primary, secondary and university level teachers and facilitators in subject-area didactics, communication and science studies. Besides, it aspires to develop innovative and user-friendly science instruction and teacher education at all levels.

## 4. Discussion

We are in the post-postmodernism era whereby neoliberal democracies are dominating the globe. We are in the era of technology and imagination. However, when we take a look at SME, in particular as they are organized in a majority of universities and higher educational institutions all over the world, it appears to many that this education is to a great extent still framed according to the outlook of Modernity (Skovsmose, 2009). Students who enter the first grade of primary school with literacy and numeracy skills have a stronger foundation for formal mathematics and science education (Mullis *et al*, 2021). Policies, Strategies and Frameworks (including 70:30 policy, Science-Technology-Mathematics-Education policy – 2016, and STEM policy – 2021) can be mentioned. Since "STEM Education" is about Critical thinking, Problem Solving, Project-based learning, Interdisciplinary fields and Techniques & methods of integration, it could serve as a domain of research. Considerable research has documented the importance of early childhood learning activities and their relationships with student achievement and other education outcomes (Mullis *et al*, 2021). An integrated STEM education is recommended (MoSHE, 2019) in combining the subjects and use of real-world problems. Thus, the curriculum and corresponding training manual should be the combination of these subjects aligned with each other.

### 4.1. Professional Development

Political regimes in the history of Ethiopia often employed the power-coercive strategy for reforming education (Tadesse *et al*, 2022). There have been interventions that target on improving the teaching and learning of science and mathematics education. Students with more opportunities to learn and more supportive learning environments consistently have higher mathematics and science achievement than those who do not (Mullis *et al*, 2021). The last decade has witnessed several concerted movements towards an integrated STEM education philosophy (MoSHE, 2019); most of the articles published in relation to Mathematics education in Ethiopia tended to process rather than its disciplinary status (Ayalew, 2019). Science Education would not be special. The dynamics of teacher educational programs over the last two decades has been affecting the discourse and progress of the subject under discussion. That is due to the fact that discourse is a function of knowledge, subjectivity and power. If reforms are introduced through the power-coercive strategy, those who initiate the reform assume the highest power which enables them to decide both on the approach and constituents of the reform (Tadesse *et al*, 2022). However, (science and) Mathematics Education is beyond that. On the other hand, practitioners and scholars in the field are not publicizing their works. Thus, a concern for, study on and practice with concepts, theories, methods, organizations, conferences and literature would be vital. It can be said that the discipline is at a premature stage in Ethiopia. Thus, mathematics education and its various sub-fields need to be promoted in Ethiopia. There have been supplementary and complementary activities in the Science and Mathematics Education, particularly in higher education institutions (HEIs).

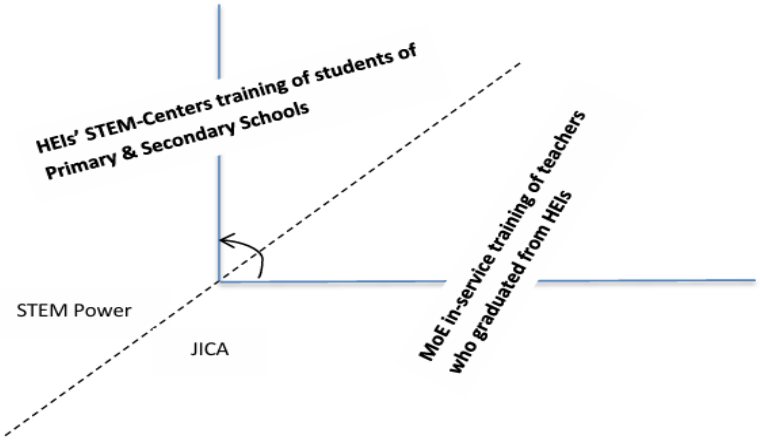


Figure 1: Complementary Roles of MoE & HEIs on Mathematics and Science Education

The above scenario might be attributed to the externalizing drawbacks and external motivation factors. It should have been a kind of warranty from HEIs' and MoE's sides though. Students who value mathematics and science are extrinsically motivated to learn these subjects because of future opportunities, such as entrance into desirable educational programs or a well-paying career (Mullis *et al*, 2021). In other words, there is vicious circle in that a teacher with limited professional capacity might produce an incompetent student who would be admitted in a HEI and end up with less motivated prospective graduates for future teaching position. In other words, if teacher educators lack sufficient and relevant pedagogical content knowledge, teachers in schools would not have sufficient pedagogical content knowledge (Getahun, 2022). Whereas the domain of MoE is student and the domain of Teacher Training Higher education institutes are teachers, MoE complement teacher's capacity and HEIs complement student's competency. Yet, this vicious circle can be resolved if the unsigned memorandum of understanding is based on a business model. For instance, if a company has defects in its product, it would be in a position to take warranty. Then, an in-service training could be a major component in the community service of a HEI. In this regard, teacher educators must be able to explain and model innovative pedagogical approaches and, in this way, enhance the instructional capacities of their students (Ahmed et al, 2019).

### 4.2. Professional Identity

Education is highly prized and teaching is a respected profession (Bethell, 2016). Cultivating among students an interest in STEM and encouraging them to study and pursue STEM as a career requires developing a strong teacher workforce (Rogers *et al*, 2015). During the TESO period, the major areas that teachers in Ethiopia should be competent in were the following. subject (s) and the content of teaching; the classroom; areas relating to the school and the education system; and the values, attributes, ethics and abilities essential to professionalism in upholding the professional ethics and producing responsible citizens (Negasi, 2015). Later in 2012, three domains of teaching were proposed: professional knowledge, practice and engagement. On the other hand, STEM center is a facility based at the University backed by an unrivalled team of experts in the fields of STEM (MoSHE, 2019). If the goal of a STEM center is to attract and inspire students towards Science and Applied Science oriented fields, then experts in STEM Education would be needed. Students who enjoy mathematics and science find the subjects interesting and are likely to be more intrinsically motivated in mathematics and science classes (Mullis *et al*, 2021). It is a practical

extendable building design that would house labs, administration, equipment storage, and auditorium suitable for science fairs and community meetings.

Focusing on STEM content knowledge and STEM pedagogical content knowledge (PCK) has been the norm of STEM professional development (Rogers *et al*, 2015). *Critical Professionalism* refers to the awareness of the connections between particular fields of knowledge and other fields, of the fact that scientific and mathematical knowledge are bounded to social action, and of the ethical dimensions of producing and applying scientific knowledge (Skovsmose, 2009). Improving the quality of teaching is the most important challenge (Bethell, 2016). So, an attempt to maintain standards could be a solution.

The national standards for teachers (MoE, 2012) in Ethiopia are: know students and how they learn; know the content and how to teach it; plan for and implement effective teaching and learning; create and maintain supportive and safe learning environments; assess, provide feedback and report on student learning; engage in professional learning; and engage professionally with colleagues, parents/care givers and the community. As it is repeatedly argued in this paper, the progress of SME has been determined by the paradigm shifts happened in teacher education. SME had been challenged on what it could mean to move beyond the assumptions of Modernity (Skovsmose, 2009). One key characteristics of the competency-based teacher education approach is that the knowledge base and skills to be mastered by prospective teachers are specified in advance (Negasi, 2015). In this regard, ability performance is assumed to be the most valid measure of teaching competence.

### 4.3. Progressing the Domain of Knowledge

Areas of research in the field of *SME* could include: General Science Education, Mathematics Education, Physics Education, Chemistry Education, Biology Education, Science Teacher Education, Mathematics Teacher Education, Environmental Science Education, STEM Education, Library and Information Science Education, and Statistics Education.

It has been suggested that one of the key factors contributing to the success of the countries of East Asia which consistently top in students' competencies in Mathematics and Science is the prevailing 'culture' and hard work (Bethell, 2016). One can assume a perspective from where one can identify knowledge-guiding interests included in so-called technical disciplines like science

and mathematics (Skovsmose, 2009). On the other hand, SME has been evolving as far as quality of education takes a concern.

There is a need of reshaping the training of science and mathematics educators with $TPCK$ model (Ahmed *et al*, 2019). The abbreviations $TPCK$ correspondingly refer to technology, pedagogy and content knowledge. Since there have been arguments and sometimes disparities on the area of knowledge to prioritize, the order may be reversed like: $C - P - T$. This matters in geometrical point of view; it is considered as orientation. Thus, the $TPCK$ model may be re-conceptualized as $C - P - T$ integrated competency as long as competent graduates are demanded. Besides, Ethiopia has been tempting a competency based (teacher) education. A teacher has to be equipped with appropriate knowledge, attitude, and skills. The three domains of teaching (knowledge, practice and engagement) are expected of teachers (MoE, 2012). Thus, there is a need to consider "beyond knowledge".

Thus, the $(T)PCK$ model of [curriculum development for] Teacher Education can be seen from geometrical orientation point of view as: $T - P - C - K$ or $K - C - P - T$. However, it would be seen algebraically too. That is, chain of T, P, and C on K as: $TPC(K) = T \circ P \circ C(K) = T\left(P\left(C(K)\right)\right)$ where $\circ$ refers to composition. First, we secure [subject matter] content knowledge$C(K)$; then, pedagogy of content knowledge$P\left(C(K)\right)$; finally, the use of technology in the pedagogy of content $T\left(P\left(C(K)\right)\right)$. This orientation may answer the question "what matters most?" in teacher education and training.

## 5. Conclusion

In this study, two underlying perspectives are identified: the educational/training practices in subjects and the field as a domain of knowledge. Many institutes have contributed to the evolvement of SME in Ethiopia. Overall, the pull-push scenario has impacted on the status of field. Accordingly, various *supplementary* roles and *compulsory* actions have been in place in the education system. This study would have potential implications for shaping mathematics and science education policies and curricula. Again, it could serve as spring board for promoting the field in knowledge, research and practice.

**Acknowledgment**

I am grateful to many contributors who shared their thoughts with me.

**Disclose Conflicts of Interest**

This paper is free of conflict of interest.

**References**

Ahmed, A.Y., Debele, M.L., Gebremeskel, H.H., Getahun, D.A., Tiruneh, D.T. & Wondem, D.T. (2019). Teacher Education in Ethiopia: Reshaping the Training of Science and Mathematics Teacher Educators. In T. Halvorsen, K.S. Orgeret & R. Krøvel (eds.) Sharing Knowledge, Transforming Societies: *The Norhed Programme* 2013–2020, 249-267.

Ayalew, Y. (2019). Mathematics Education in Ethiopia: A Systematic Review of Twenty Years of Discourses on the Discipline. A Paper presented on the 1st International Conference on Science and Mathematics Education 23rd -25th October, Bahir Dar, Ethiopia.

Belay, S., Atnafu, M., Michael, K. & Ermias, A. (2016). Strategic Policy for National Science, Technology and Mathematics Education. MoE and JICA, Addis Ababa.

Bethell, G. (2016). Mathematics Education in Sub-Saharan Africa: Status, Challenges and Opportunities. The World Bank: Washington, DC.

Engida, T. & Areaya, S. (2008). Science and Mathematics Education in Ethiopia: Policy, Curriculum and Implementation. In R.K. Coll & N. Taylor (eds) Science in Context: An International Examination of the Influence of context on Science Curricula Development and Implementation. Sense Publishers, Rotterdam.

Getahun, D. A. (2022). Scientific Reasoning Among Teachers and Teacher Trainees: The Case in Ethiopian Schools and Teacher Training Colleges. *International Journal of Science and Mathematics Education*, 20(1), 1-17.

JICA (2017). Project for Capacity Development for Improving Learning Achievement in Mathematics and Science Education in the Federal Democratic Republic of Ethiopia (LAMS) Project Completion Report submitted to the Federal Democratic Republic of Ethiopia Ministry of Education.

Kobayashi, V. (2019). Reflections on STEAM in Education. In Z. Babaci-Wilhite (ed.), *Promoting Language and STEAM as Human Rights in Education*, 177-187.

Mathew, T.M. (2014). *Information Science Education in Ethiopia: An Overview*. European Academic Research, I (10), 3385- 3393.

MoSHE (2019). National STEM Framework, Addis Ababa, Ethiopia.

MoSHE (2020). Science Policy and Strategy of Ethiopia, Addis Ababa, Ethiopia.

MoE (2012). Professional Standard for Ethiopian School Teachers. Addis Ababa, Ethiopia.

MoE (2021a). Guidelines for Science Fair (working document), Addis Ababa, Ethiopia.

MoE (2021b). Baseline Survey on the Status of and Functionality of Science and Mathematics Laboratories in Ethiopian Primary and Secondary Schools, Mathematics ad Science Education Improvement Center, Addis Ababa, Ethiopia (Unpublished).

Mullis, I.V.S., Martin, M.O. & Davier, M.V. [Eds.] (2021). *TIMSS 2023 Assessment Frameworks*. TIMSS & PIRLS International Study Center, Boston.

Negasi, R.D. (2015). Competency-Based Secondary Teacher Education Program in Ethiopia: Potential Opportunities and Obstacles. *Bahir Dar Journal of Education*, 15(1), 41-64.

Rogers, R. Winship, J. & Sun, Y. (2015). Systematic Support for STEM Pre-Service Teachers: An Authentic and Sustainable Four-Pillar Professional Development Model. In K. Dikilitaş (ed.) Innovative Professional Development Methods and Strategies for STEM Education, 73-90.

Sbhatu, D. B. (2021). Challenges of 20th Century Ethiopian Science Education. *Heliyon*, 7 (e07157), 1-12.

Skovsmose, O. (2009). Towards a Critical Professionalism in University Science and Mathematics Education. In O. Skovsmose, P. Valero O. Christensen (eds) University Science and Mathematics Education in Transition, Springer Science + Business Media, P. 325-346.

Tadesse, A., Kenea, A. & Woldemariam, K. (2022). Ethiopian Education Reform: From Tradition to Nowhere: A Systematic Literature Review. *Ethiopian Journal of Education & Science*, 17(2), 1-17.

Referred Websites:

https://dfsme.org/back (Accessed on 23th October, 2024)

https://www.csuchico.edu/cmse (Accessed on 23th October, 2024)

https://casme.org.za/about (Accessed on 23th October, 2024)

https://kue.edu.et/college-of-science-mathematics-education (Accessed on 21st December, 2024)