Original Article

Trends and Orientations in Science and Mathematics Education in Ethiopia

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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. The analyses revealed two primary perspectives: first, education and training practices within specific subjects, and second, the field as a domain of knowledge and research. On one hand, emphasis was placed on curriculum and policy matters, teaching and learning methods, textbook research and development, lesson study, contextual considerations, and teacher training. On the other hand, the field of Science and Mathematics Education has been developing across four main hubs of study and practice. 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 example, the Delaware

Foundation for Science and Mathematics Education in the USA, established in 1995, focuses on promoting STEM fields, STEM education, and STEM-related careers. Similarly, the Center for Mathematics and Science Education at California State University, founded in 1993, is a non-profit organization that connects the University, colleges, K–12 schools, and the business sector to advance mathematics and science education. Additionally, the Centre for the Advancement of Science and Mathematics Education in South Africa serves as a dynamic force driving innovation in STEM. These examples illustrate that STEM initiatives are integral components of 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 have increasingly advocated for a stronger focus on Science, Technology, Engineering, and Mathematics (STEM) across all levels of education, from primary schools to higher education (Belay et al., 2016). Consequently, pre-service teacher education programs were revised, and new in-service training initiatives were introduced to better equip 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' achievement in science and mathematics subjects has consistently fallen below the basic proficiency level (Getahun, 2022). Moreover, the historical development of the country's science education system has not been thoroughly examined (Sbhatu, 2021), leaving the field's status as a domain of research, practice, and scientific inquiry largely unstructured. Notably, the topic of "Science and Mathematics Education in Ethiopia" was first formally 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

Essentially, STEM represents an educational initiative that adopts an integrative approach to equip students with critical thinking skills, problem-solving abilities, and the capacity to contribute to advancements in science and technology (MoSHE, 2019). This comprehensive integration also reflects an awareness of the need for students to engage meaningfully in a globally connected and rapidly changing society (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 context, teachers are key stakeholders. STEM lessons or units are generally structured around solving real-world problems and emphasize project-based learning, making STEM an interdisciplinary approach that integrates academic concepts with practical applications. By engaging students with STEM and providing opportunities to explore related concepts, educators aim to foster a passion for innovation and encourage students to pursue careers in STEM fields. At BDU, a pioneering initiative is the STEM Center, which hosts programs such as summer outreach for talented students, Math Camps, and the Science Shared Campus program. The two-year outreach program, funded by Mr. Mark Gelfand, aimed to increase the number of students pursuing science and technology, guided by the motto: "Inside every child, there is a scientist."

> *…The training was designed as hands-on, practical laboratory work and was conducted in the university's on-campus laboratories. The program covered core school subjects including Physics, Chemistry, Biology, Mathematics, ICT, Electronics, Technical Drawing, and English. Additionally, extracurricular activities and educational field trips were incorporated into the program. A "team teaching" approach was implemented, involving one university instructor, one laboratory technician, and one school teacher per session. Each class accommodated 25 students who engaged in three hours of laboratory work per session (Email correspondence with informant 2, 25th 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.

> *The Math Camp program at the Department of Mathematics, BDU, began in July 2012. Held annually from June to July on the main campus, the camp lasts for two weeks and aims to make mathematics engaging, enjoyable, and stress-free. Rather than being solely focused on math instruction, the program incorporates computer programming, computer graphics, physical activities, socialization, and leadership development. Students are accommodated in university dormitories and participate in recreational activities across dorms, athletic fields, and classrooms. In addition, the University runs an annual STEM Girl's Camp for talented female students in grades*

> *nine through twelve. Launched in January 2014 at the STEM Center, this camp also takes place during the semester break on the main campus and lasts for two weeks (Email correspondence with informant 12, 25th Dec. 2022).*

Currently, Ethiopia hosts multiple STEM centers that aim to transform learning beyond rote memorization of facts and formulas, emphasizing a deep understanding of the scientific and mathematical principles underpinning modern engineering and technological innovations (Ahmed et al., 2019). In addition, the Science Shared Campus initiative provides laboratory-based instruction in STEM-related school subjects and English by university instructors, while other school subjects are taught by teachers from nearby government schools. Programs of this kind are implemented at institutions such as Bahir Dar University, Kotebe University of Education, and Hawassa University.

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 24th 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 carried out in a different region of Ethiopia revealed that teacher educators, schoolteachers, and prospective teachers exhibited low levels of scientific reasoning skills (Getahun, 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 are closely linked to the concept of Modernity, with the Scientific Revolution serving as a gateway to modern ways of thinking. However, as previously noted, Modernity has also been associated with colonization, oppression, and the imposition of certain ways of thinking and acting. This critical perspective is an important component of professional awareness in the field (Skovsmose, 2009). Moreover, many science and mathematics teacher educators at colleges are subject specialists who possess limited pedagogical content knowledge (Ahmed et al., 2019). They often come from an older educational tradition that prioritized mastery of subject matter as the primary indicator of quality teaching and learning. Consequently, there is a

pressing need to implement targeted teacher educator training programs that strengthen their pedagogical content knowledge (PCK) and enhance teaching effectiveness (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

In alignment with the Government's directive to differentiate Higher Education Institutions, Kotebe University of Education (KUE) has undertaken a revision of its organizational structure and academic programs. The College of Science & Mathematics Education at KUE comprises the Departments of Biology Education, Chemistry Education, Information Technology Education, Mathematics Education, and Physics Education. The college prepares future teachers and facilitators for primary, secondary, and tertiary levels, equipping them with expertise in subject-specific didactics, communication skills, and scientific knowledge. Additionally, the college aims to foster innovative, accessible, and effective approaches to science instruction and teacher education across all educational 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 examining Science and Mathematics Education (SME) as it is structured in most universities and higher education institutions worldwide, it becomes evident that much of this education remains heavily influenced by the perspectives and assumptions of Modernity (Skovsmose, 2009). Students who begin primary school with pre-existing literacy and numeracy skills tend to have a more solid foundation for succeeding in formal mathematics and science instruction (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. Given that STEM education emphasizes critical thinking, problem-solving, project-based learning, interdisciplinary integration, and diverse instructional methods, it represents a rich domain for research. Substantial evidence highlights the significance of early childhood learning experiences, showing strong correlations with later student achievement and broader educational 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

Throughout Ethiopia's history, political regimes have often relied on power-coercive strategies to implement educational reforms (Tadesse et al., 2022). Specific interventions have targeted the improvement of teaching and learning in science and mathematics education, as students exposed to more learning opportunities and supportive environments consistently demonstrate higher achievement in these subjects (Mullis et al., 2021). Over the past decade, there has been a growing movement toward adopting an integrated STEM education philosophy (MoSHE, 2019). However, much of the published research on mathematics education in Ethiopia has focused on processes rather than its disciplinary status (Ayalew, 2019), and the same likely applies to science education. The evolution of teacher education programs over the last twenty years has shaped the discourse and development of the field, reflecting the interplay of knowledge, subjectivity, and power. Reforms implemented through coercive power typically allow reform initiators to dictate both the approach and content, leaving little room for practitioner or scholarly input (Tadesse et al., 2022). Moreover, many scholars and practitioners in science and mathematics education have not widely disseminated their work, limiting engagement with concepts, theories, methods, organizational structures, conferences, and literature. As a result, the discipline remains in a relatively nascent stage in Ethiopia. There is a clear need to strengthen mathematics education and its subfields while continuing supplementary and complementary initiatives in Science and Mathematics Education, particularly within higher education institutions.

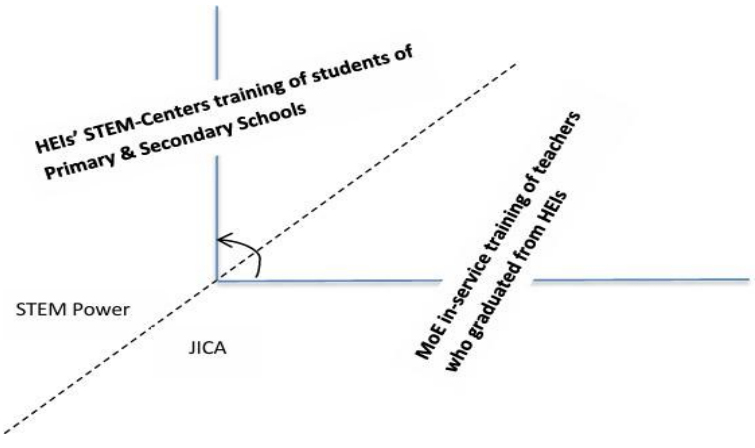

Figure 1: Complementary Roles of MoE & HEIs on Mathematics and Science Education

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 perceive mathematics and science as valuable tend to be extrinsically motivated, driven by the potential benefits these subjects offer, such as gaining access to preferred educational programs or securing well-paying careers in the future (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 valued, and teaching is regarded as a prestigious profession (Bethell, 2016). Fostering students' interest in STEM and motivating them to pursue STEM careers depends on cultivating a capable and committed teacher workforce (Rogers et al., 2015). During the TESO period in Ethiopia, teachers were expected to demonstrate competence in four key areas: mastery of subject content; effective classroom management; understanding of school operations and the broader education system; and possession of the professional values, ethics, and skills necessary to uphold ethical standards and produce responsible citizens (Negasi, 2015). By 2012, these expectations were refined into three teaching domains: professional knowledge, practice, and engagement. Complementing these efforts, STEM centers at universities provide specialized facilities and are staffed by experts in STEM education (MoSHE, 2019). These centers aim to attract and inspire students toward science and applied science fields. Students who enjoy mathematics and science tend to find these subjects intrinsically interesting, enhancing their engagement and motivation (Mullis et al., 2021). Practically, STEM centers are designed as

multi-functional buildings that include laboratories, administrative offices, equipment storage, and auditoriums suitable for science fairs and community events.

Professional development programs in STEM have traditionally concentrated on strengthening teachers' mastery of subject matter as well as their STEM pedagogical content knowledge (PCK) (Rogers et al., 2015). However, the concept of critical professionalism highlights the need for educators to understand how disciplinary knowledge connects with other fields, how scientific and mathematical knowledge interacts with social realities, and the ethical responsibilities involved in producing and applying such knowledge (Skovsmose, 2009). In this regard, improving the overall quality of teaching remains one of the most pressing challenges in education systems (Bethell, 2016). Consequently, establishing and maintaining clear professional standards and quality benchmarks for teaching can be considered an important strategy for enhancing instructional effectiveness.

In Ethiopia, the national standards for teachers outlined by the Ministry of Education emphasize several core competencies, including understanding students and how they learn; mastering subject content and appropriate teaching methods; planning and implementing effective teaching and learning processes; creating supportive and safe learning environments; assessing, providing feedback, and reporting on student learning; engaging in continuous professional learning; and maintaining professional engagement with colleagues, parents or caregivers, and the wider community (MoE, 2012). As frequently argued in this paper, the advancement of Science and Mathematics Education (SME) has been closely linked to paradigm shifts in teacher education. In particular, SME has been challenged to reconsider its foundations and move beyond the assumptions associated with modernity (Skovsmose, 2009). Within this context, the competency-based teacher education approach has gained prominence. A key feature of this approach is that the knowledge and skills expected from prospective teachers are clearly defined in advance (Negasi, 2015). Consequently, the demonstration of practical teaching performance is regarded as the most valid indicator of teacher 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: $TPC(K) = T \circ P \circ C(K) = T\ (P(C(K)))$ where $\circ$ refers to composition. First, we secure [subject matter] content knowledge$C(K)$; then, pedagogy of content knowledge$P(C(K))$; finally, the use of technology in the pedagogy of content $T\ (P(C(K)))$. 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.

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Disclose Conflicts of Interest

This paper is free of conflict of interest.

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