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Breaking Barriers to Women's Participation in Science, Technology, Engineering and Mathematics in Ethiopia

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Acronyms

ESDP	Education Sector Development Program
FDRE	Federal Democratic Republic of Ethiopia
HEI	Higher Education Institutions
MoE	Ministry of Education
SDGs	Sustainable Development Goals
STEM	Science, Technology, Engineering, and Mathematics
UNESCO	United Nations Educational Scientific and Cultural Organization

Abstract

   Nations across the globe are striving to achieve the 2030 Sustainable Development Goals adopted by the United Nations. Science, Technology, Engineering, and Mathematics (STEM) is expected to play crucial roles in achieving these sustainable development goals. Unfortunately, most countries in Africa are not fully utilizing the potential of their entire population, including girls and women. The participation of women in STEM is paramount to improving women's economic security and stability, ensuring a diverse and talented workforce, and augmenting national development efforts. With this understanding, countries like Ethiopia have taken policy measures intended to increase the proportion of women in STEM fields of study, employment, and leadership in higher education institutions. This study sought to understand if and how various policies implemented by the Ethiopian government have addressed gendered disparities in STEM in the country's public higher education system. To do this, 20 years of enrollment and graduation rate data from 45 public universities in Ethiopia was digitized and analyzed. In addition, interviews and questionnaires were administered to university students and faculty members at three public Ethiopian universities to understand the challenges women experience participating in STEM studies and to identify best practices that could increase women's participation in STEM fields of study. Results indicate that these policies have made some positive contributions in terms of moving toward gender parity in admission rates in STEM-related disciplines in the public higher education sector at the undergraduate and graduate levels. For example, women's enrollment in engineering and technology programs increased from 20.9% in 2008 to 27.3% in 2017/18. Similarly, women's enrollment in postgraduate programs in engineering and technology fields increased from 3.5% in 2007 to 15.9% in 2017, with a ten-year average enrollment rate of 12%. Furthermore, women's enrollment in STEM-related science fields (e.g., biology, chemistry, statistics, and mathematics) in the higher education sector has shown significant progress. For instance, in 2008, women enrolled in undergraduate science fields accounted for 23.7% and reached 49% in 2017, with an average ten-year enrollment rate of 34.7%. Yet, results illustrate that once women are admitted to the university, few policies and supports are in place to ensure that they complete their studies, resulting in much higher attrition in these fields than their male counterparts. For instance, on average, 25% of female students at public universities are academically dismissed from their studies, compared to 8% of male students. These high rates of attrition then result in fewer women engaging in post-graduate studies in these fields, pursuing academic careers, and holding senior leadership positions in academia. In 2015, for instance, only 12.3% of faculty members of public universities were women, and no university had a woman president or vice president. Thus, these findings highlighted the strong need to further understand the various challenges women experience in completing their STEM degrees once admitted to their programs of study, as well as how policies and supports can be implemented to address these challenges. By taking these steps, we can ensure not only access for women students to their STEM studies but also access with success.

Key words: STEM, Higher education, Women in STEM, gender gap, Ethiopia

1. Research problem

Science, Technology, Engineering, and Mathematics (STEM) can play a crucial role in facilitating the social and economic development of countries by tackling some of the greatest challenges of the 21st century (Adefunke & Negar, 2016). STEM produces skilled and trained individuals who can contribute to countries creation of inclusive and sustainable societies by advancing information and communication, fighting diseases, developing industries and technologies, and tackling climate change, among others (Bello, 2020). Furthermore, as scholars (e.g., Bello, 2020; Munoz Boudet et al., 2021) described, STEM careers are perceived as jobs of the future. Yet, women's and girls' participation in such relevant fields of study is substantially lower than their male counterparts, with STEM disciplines being overwhelmingly male-dominated (Hill, Corbett, & St. Rose, 2010).

In many countries across the globe, women are highly underrepresented in STEM studies and careers (UNESCO, 2017). For example, global reports indicate that only seven percent of women chose to study engineering, manufacturing, or construction compared to 22 percent of men (Hammond et al., 2020), and evidence from 121 countries indicates that only 29% of women are science researchers (Ekine, Samati, & Walker, 2013). Evidence (e.g., Mukhwana et al., 2020; Kong et al., 2020) points out that complex factors, which reinforce issues at various levels (e.g., individual, social, structural, organizational, and policy levels), contribute to the underrepresentation of women in STEM.

In sub-Saharan Africa (SSA), women experience an array of challenges in the education context. Firstly, they tend to have much lower rates of admission to post-secondary studies than their male counterparts (Hammond et al., 2020). When they join university, they are less likely to pursue a study in STEM-related fields (Adefunke & Negar, 2016). For example, in some SSA countries, women represent around 50% in the humanities and arts and up to 95 percent in the life sciences, while their enrollment proportion in physics, mathematics, and engineering is as low as 10% (Polcuch, Brooks, & Bello, 2018). This gender disparity in STEM may negatively affect the socio-economic developments of Africa and its contribution to the science and innovation arena.

Like many other countries in the SSA, women and girls in Ethiopia are also significantly underrepresented in STEM studies and careers. For example, a report from ten public universities in Ethiopia showed that among the 2208 physics undergraduate enrollees, only 175 (7.9%) were female (Semela, 2010). Similarly, as per the 2006/7 national report

from the Ethiopian Ministry of Education, the highest proportion of female students (75%) joined undergraduate social science fields, while the rest (25%) enrolled in STEM and life sciences.

The stark gender disparity in Ethiopian higher education institutions is also reflected in the academic employment and leadership participation of women. For example, the proportion of female faculty members in the public universities of Ethiopia is less than 10% (van Eerdwikk et al., 2014). On the leadership level, up until 2015, the country's Ministry of Education illustrated that there was only one woman vice president from two-dozen public universities, despite a policy clearly stating that, by the end of 2015, there should be at least 16 women leaders as president or vice president (FDRE, 2010b).

The equal participation of women in all fields of study, especially increasing their participation in STEM, helps reduce the gender pay gap, improves women's economic security and stability, and ensures a diverse and talented workforce (Bello, 2020). Besides, national development efforts are augmented when women's equal access to science and technology is ensured (UNESCO, 2017; Yang et al., 2022). Furthermore, gender disparity in STEM could contribute to the underutilization of talents and perspectives (UNESCO, 2010) and result in an inefficient allocation of labor and talent and a missed opportunity for economies (Hammond et al., 2020).

In most indicators of sustainable development and innovation capabilities, Ethiopia ranks among the least-performing countries in the world. For example, Ethiopia ranked 117 among the 132 economies featured in the 2022 Global Innovation Index (Dutta et al., 2022) and third among the 12 low-income group economies. Such a limited development and innovation context necessitates the full utilization of the country's human potential, meaning that Ethiopia cannot afford to have half of its population, women, missing from the STEM workforce. Moreover, Ethiopia aspires to achieve the minimum threshold of a middle-income country by 2030, and the Ethiopian government expects science and technology to play a significant role in meeting its development and growth targets (FDRE, 2010a).

Given this goal, the Ethiopian government has devised and implemented some policies with the intention of increasing the proportion of women in STEM studies in the country's public higher education system, as well as academic employment and leadership within this system. For example, affirmative action for admission (FDRE, 1998), scholarships

for female students and a 30 percent seat quota for female students in each university department (FDRE, 2002; FDRE, 2006), leadership skills development programs for women faculties, and affirmative action in university hiring (FDRE, 2010b; FDRE, 2015) are some of the policy initiatives that the government has introduced.

Thus, the objective of this study was to understand if and how these recently implemented policies have improved women university students and researchers' access to participate and lead in STEM fields in the Ethiopian higher education context. Such an investigation is important because previous studies (e.g., Semela, 2010; van Eerdwikk et al., 2014) have not investigated the effectiveness of these recently introduced policies that are intended to address barriers to women's access and success in the Ethiopian higher education context. Given the larger research gap this study sought to fill, the specific research questions were as follows: 1) If and how have the policies implemented by the Ethiopian Ministry of Education (MoE) and various universities in the country enhanced gender equality in STEM enrollment, employment, and leadership at Ethiopian universities? 2) If and how do women still experience barriers to participating in STEM disciplines in the Ethiopian higher education context? 3) What best practices and policies could improve women's participation in STEM fields of study in the Ethiopian higher education context?

2. Objective

In this study, our principal objective was to generate evidence to assist the government/Ministry of Education of Ethiopia and universities to better understand if and how their recently implemented gender equality policies have increased women's participation in STEM studentship, leadership, research, and employment in the country's public higher education system, and, if required, how these policies and university practices might be improved to further increase women's participation in these fields. It was also intended for such findings to contribute to current knowledge on the state of women's participation in STEM fields in Southern higher education systems and the reasons for their limited participation. The following section explores the study's specific objectives and if and how these objectives were achieved or changed during the project's lifespan.

Specific Objectives:

1. To explore the status/trends of women in STEM enrollment, leadership, and employment situations in the Ethiopian higher education institutions.

To address this objective, 20 years (from 19996/7to 2017/8 academic years) of administrative data were organized, digitized, and analyzed. This data was obtained from the Ministry of Education's annual statistical report, which the ministry compiles by collecting it from all public universities. The ministry of education collects enrollment and graduation data, the number of academic staff, and leadership-related data from all public universities. In addition, we have made a critical and in-depth evaluation of education policy and strategy documents, with specific emphasis on the higher education system and on women and STEM studies.

The analysis focused on the trends in women's enrollment and graduation rates from Ethiopian public higher education, with a particular emphasis on STEM fields of study. These enrollment and graduation rates of women at public universities and specifically in STEM fields were evaluated vis-à-vis the intentions of implemented policies and specific interventions. We were also able to quantify the number of women participating in academic employment and leadership positions at higher education institutions in Ethiopia. The evidence collected and analyzed has therefore enabled us to address this objective adequately.

However, in collecting the data from the Ministry of Education, we had to overcome some challenges. For example, one of the challenges was related to data recording and management. Non-digitized data and partly damaged and missing documents have made our work very difficult and time-consuming. Some data was available in the form of Excel sheets, but a lot of missing values and inconsistent numbers made it difficult to fully utilize such electronic data. We tried to overcome this challenge by verifying and re-confirming data at the Ministry of Education with reports sent from universities. Although this has consumed our time, finances, and energy, we tried to enhance the accuracy of the data by cross-checking the data from office to office and re-confirming the data we took from lower offices with the directors and higher officials, as well as with former employees who now have moved to a different department.

on a number of occasions, the Ministry of Education notified public universities to change or adopt practices with just a brief letter without explaining the rationale, intention, or objective of the change. Such was another challenge we faced in our policy analysis. For example, we have seen letters sent to universities that notify them of changes about promotion, leadership participation rules, and grading systems, among others, without giving much explanation.

2. To identify the challenges/barriers women experience in participating in STEM studies, leadership, and employment in Ethiopian higher education institutions.

To address this objective, we have collected primary data from students, policymakers, faculty members, and individuals with leadership rank at public universities. We collected data from these participants through questionnaires and interviews. The questionnaires and interview questions tried to explore the challenges and experiences that female students had to go through in their pursuit of STEM studies. Interviews with policymakers, experts, and high-level university leaders focused on understanding the policy level, systemic, and structural challenges and barriers that women faced in STEM studies, employment, and leadership participation in the higher education system.

The outbreak of COVID-19 and the war in northern Ethiopia were some of the prominent challenges that we faced in collecting the data to meet this sub-objective. For example, participating universities were closed for up to ten months due to the COVID-19 pandemic, and this significantly disrupted our overall schedule. In addition, road closures, protests, and restrictions on entering universities for security reasons were some of the challenges we faced, and these delayed some of our activities from being completed based on our initial schedule. Moreover, we were not able to meet some of the participants and research assistants initially recruited for our research purposes after the reopening of universities.

Several steps were taken to overcome these challenges. For example, we tried to interview willing participants via phone call, let participants self-rate questionnaires and respond to questions in written form, and adhere to COVID-19 protection rules such as wearing masks and keeping a safe distance during interview sessions. We also retrained research assistants and data collectors on COVID-19 safety rules and how they would implement them whenever they traveled to conduct fieldwork and meet people.

3. To explore what best practices are available and what policy changes at both the national and university level could be made to increase the participation of women students, researchers, and leaders in STEM fields in higher education institutions in Ethiopia.

Strategies and best practices that could work to enhance women's participation in STEM fields in the Ethiopian higher education sector were explored through a literature review, interviews with STEM experts, and an analysis of current promising practices in universities. A rapid scoping review of different databases related to interventions that

sought to increase women's participation in STEM was conducted. Applying affirmative action, introducing mentoring programs, building a supportive environment within universities, creating coordination among actors, and expanding STEM centers within universities are some of the strategies uncovered.

3. Methodology

This study used a mixed research design approach to understand the rate of women's participation in STEM fields of study as students (undergraduate and graduate), researchers, and leaders in the Ethiopian higher education context in light of policies that have been implemented over the past 20 years to increase women's enrollment in these fields of study. It also examined barriers that prevent or limit women students or researchers' participation in STEM fields, and potential ways in which national and institutional policies and initiatives could be strengthened to increase women's participation in STEM fields, leadership, and employment in this domain in the country. The approach was more inclined toward quantitative data.

3.1. Method-I-Policy mapping/ analysis

The first component of this project (objective one) focused on understanding the Ethiopian national policy context by analyzing the various policies and strategies that have been developed and implemented in the country to increase women's participation in STEM fields of study, employment, and leadership in the Ethiopian higher education context. The following national education policy and strategy documents that relate to the provisions of the higher education system and STEM in Ethiopia were reviewed.

- The successive Education Sector Development Programs (ESDPs)
  - ESDP-I (1997-2002)-ESDP
  - ESDP-II (2002-2005)-ESDP-II
  - ESDP-III (2005-2009)-ESDP-III
  - ESDP-IV (2010-2015)-ESDP-IV
  - ESDP-V (2015-2020)-ESDP-V
- The 2003 and 2009 higher education proclamations (2009 proclamation &2003)
- The 1994 education and training policy(ETP)
- The education and training policy and its implementation (policy and implementation)
- Education development roadmap (Roadmap)

- The national development strategy documents ([Growth and transformation plan-I](#)& [GTP-I](#)I)

The policy analysis was conducted by reviewing the documents, particularly focusing on the goals, rationales, intentions, and expected outcomes. Each policy or strategy implemented was also analyzed to assess if and how it achieved its intended target and overall expected outcomes based on findings from the analysis of this study's second method employed – analysis of administrative data, which will be discussed in the following section.

3.2. Method II-Administrative data analysis

Reports and annual educational statistical data on student enrollment and graduation rates, as well as data related to faculty members and women leaders in higher education institutions, were collected from the Ministry of Education of Ethiopia. To assess the success and gaps in policies and the changes as a result of such policy implementation, a trend analysis on undergraduate and postgraduate students' enrollment, the proportion of women faculty members employed in universities, and the level of women's participation in leadership positions in Ethiopia's public higher education institutions was done.

The Ministry of Education annually collects data from all the education systems (from elementary schools to universities). The Ministry then organizes this data and prepares it in a report form dubbed as the annual educational statistical report. This larger annual report has a section dedicated to statistical information from universities. This part of the data is drawn from 45 public universities that directly accept undergraduate students from high schools. For this study, it was therefore necessary to review all annual reports and digitize them for further analysis. As the data is not in an electronic form, reviewing all reports manually and, when necessary, reconfirming the data with the reports sent from universities was done.

3.3. Method III-primary data collection

For the second objective, assessing the barriers to women's participation in STEM undergraduate programs of higher education, primary data was collected from three public universities: Debarik, Bahirdar, and Debiretabor. Letters were sent out to a dozen universities requesting permission from the HEIs senior administration to participate in this study. However, only these three universities confirmed their willingness to participate with a formal letter and pledged to support the research process from the beginning to the end. Ethical clearance was also obtained from the University of Gondar's ethical review board, which serves all other participating institutions (see Appendix I). Surveys and interviews were then used at these three study sites: These methods are described in further detail below.

Interview: Structured interviews were conducted with women at these three universities who were categorized as follows: women students currently enrolled in STEM studies; women students who changed their field of study from one in the STEM field to one in the social sciences; and women staff members holding leadership positions at these institutions (e.g., gender office heads and directors). We have also interviewed male faculty members, top-level university leaders, and educational policy experts at the Ministry of Education. A total of 16 interviews with individuals from the various participant groups, as described in the following table, were conducted.

Table 1: Interview participants

groups	Number of participants
Policy experts	2
STEM students (girls)	7
Social science students (shifted from STEM	2
University leadership (V/president, gender office directors)	3
Faculty members	2
Total	16

The interview questions captured information including women's general views of STEM, the potential barriers for women to join STEM and factors that hinder their success in STEM, the current practices to support women in STEM, the policy context on gender and STEM in the Ethiopian HEI context, and what needs to be done to address the gender gap in STEM in this context (see Appendix-II for the full interview guides). The interview questions also explored women's experiences related to leadership, hiring, and promotion at their respective universities.

Survey: A survey questionnaire was prepared and distributed to the graduating class of STEM students at each of the three universities participating in this study. The questionnaire was prepared through reviewing previous research (e.g., Tizikara, Nakayiwa-Mayega, & Otto, 2019; Semela, 2010; Salami, 2007) and based on instruments that other similar previous studies have employed. The questionnaire covered issues such as demographic information, experiences of women students in universities, potential barriers to women's success in STEM including cultural issues, organizational environments, and

individual related factors. A pilot test was conducted on a small sample (N= 15) drawn from the University of Gondar. The draft instruments were given to three psychometric teachers, two Amharic language experts, and two English language professionals. Based on their feedback, some items were improved, some others discarded, and the order of questions was rearranged.

Using Taro's (2010) formula, the sample size was statistically determined based on the total number of graduating STEM students, with a 5% margin of error, and a return rate of 80%. The sample size required for this study was found to be 284 male and female students. Male STEM students were included in the study to obtain an understanding of the possible cultural, attitudinal, personal, and systemic challenges that female students may experience in their studies as well as to determine if they have been treated differently than their counterparts in their STEM education journey. Comparing perspectives and experiences between the genders also enabled the study team to understand if a difference might exist between young women's and young men's perceptions of themselves about STEM as well as their experiences and perceptions towards STEM. A total of 207 students (105 females and 102 males) completed the questionnaire.

Table 2: Survey participants along with their university and field of study

	Engineering & technology	Natural science& agriculture	total	remark
Bahirdar university	65	28	93	
Debiretabor university	42	20	62	
Debarik university	0	52	52	No engineering fields
Male	67	35	102	
Female	42	63	105	
Total	109	98	207	

The number of students was distributed to the three universities based on the size of their graduating students. Accordingly, 45% of the participants were from Bahirdar University, 30% from Debiretabor University, and 25% from Debark University. Nearly fifty-five percent of the participants were from engineering and technology fields of study, and the rest, 45%, were from computational and natural sciences, which include agricultural sciences.

In obtaining participants' consent, we explained the purpose of the study verbally, providing all information related to the objectives, procedures of the study, and who is responsible for this study, and allowed them to ask if they had questions or concerns. After obtaining participants' verbal consent, they were asked to sign an informed consent form (see Appendix IV). We have also asked for our interviewees' consent so we can record the interview sessions. Nonetheless, most of the interviewees were hesitant about the tape-recording idea. We then agreed to write down all the conversations during the interview sessions. We also informed them that the following procedures would be taken:

- We would use study codes on data documents, and no names would be taken and reported.

- Information that links the study code to subjects' identifying information, if any, would be kept in a separate document. These documents would be locked in a separate location, and access to them would only be allowed to the researchers.

- Any identifiable data from the survey or the interview would be encrypted (such as references to the university's location).

- Face sheets from survey documents or interview transcriptions would be made to avoid any identifiable information about the participant.

3.4.Method IV-Literature review

The third objective of this study was to explore best practices and strategies that would increase the participation of women in STEM fields of study in the Ethiopian higher education context. To address this objective, a rapid scoping review of interventions targeting women and STEM in higher education contexts, preferably tested in African contexts, was undertaken.

We made electronic searches such as on Scopus, Taylor & Francis, SAGE publications, PsycINFO, Google Scholar, the Public Library of Science, and other education-related databases and search engines, including Education Abstracts, Social Science Abstracts, and ERIC. We used key words pertaining to women, higher education, sub-Saharan Africa, STEM enrollment, retention, barriers, higher education leadership, faculty members, intervention, and best practices. We also searched grey literature on the websites of organizations that deal with issues related to STEM and women (e.g., UNESCO website).

Obtaining well-tested, evaluated, and scaled approaches to increase women's participation in STEM fields of study in African higher educations was very limited. We used additional approaches, including hand searches of journals based on sample studies,

backward (ancestry) searches of reference lists in identified articles, and forward searches of articles that have cited key studies.

3.5. Data analysis

Descriptive statistics like percentages and graphs were used to analyze the quantitative data that was obtained from the MoE. This analysis depicts the patterns of undergraduate and graduate enrollment and graduation rates over time (from 1996/97 to 2017/18 academic years), with a focus on STEM fields, at Ethiopia's public universities. Similar to this, this descriptive analysis included the percentage of women faculty members and the participation of women in leadership in Ethiopia's public higher education. Along with this quantitative analysis, a policy analysis was also carried out to investigate how the adoption of various policies over multiple time periods affected the trends for female enrollment and graduation in STEM fields, female leadership participation, and female faculty employment.

The policy analysis was essential to explaining the observed changes (increase or decrease) in the trend of female participation in higher education and in STEM studies. Accordingly, using the policy analysis framework of Taylor, Rizvi, Lingard, and Henry (1997), in this analysis, three aspects of the policies were considered: context, text, and consequences. In the context aspect, the analysis considered the antecedents of the policy, including the issues and pressures that give rise to the needs of the policy. Secondly, the analysis considered the texts of the policy documents, interrogating the purpose and the values that underpin the policy. Finally, the analysis considered the policy consequences of the way it was implemented, the challenges to implementing the policy, and the results due to the policy practice. In analyzing the quantitative data obtained through the questionnaire, a similar descriptive analysis including percentages, graphs, mean, and median, was used.

Finally, the qualitative data obtained through interviews with policymakers, women in STEM, students, and leaders at various levels was analyzed in the form of thematic analysis. In the first phase of the analysis, we looked for themes directly related to the second objective, which is identifying the barriers women experience in participating in STEM studies, leadership, and employment in Ethiopian higher education institutions. Hence, researchers came together with the interview data they collected to share and discuss themes that are related to this objective. In the second round of coding, we thematically organized the barriers into several themes, including patriarchal/socio-cultural barriers, systematic barriers, labor-market related barriers, and individual-level barriers. The coding decisions at each

stage were made after the researchers reached an agreement over their discussion. These qualitative findings were used to establish and understand the quantitative data.

4. Project activities

To achieve the aims of this research project, various activities were conducted throughout the course of the project, which are outlined in Table 3 below. These activities were essential in addressing bureaucratic issues, accessing the required data, and identifying potential participants for this study.

Table 3: Main project activities

s/n	Activities	Participants	Date	Place
1	Exploratory visits	Researchers	Feb 20-Mar 18, 2020	Bahirdar, Debretabor, Addis Ababa, Debark
2	Meetings with organizational leaders	Researchers	March 27-May 3, 2020	Bahirdar, Debretabor, Addis Ababa, Debark
3	Meetings with lower level supervisors	Researchers	March 27-May 30, 2020	Bahirdar, Debretabor, Addis Ababa, Debark
4	Processing ethical clearance	Researchers	May 30-June 11, 2020	Gondar
5	Recruiting and training of research assistants and data collectors	Researchers, hired experts	July 25-Aug 25, 2020	Gondar, Bahirdar
6	Policy mapping	Researchers, experts	Aug 20-Jan 15, 2021	Bahirdar, Addis Ababa
7	Preparing instruments	Researchers, experts	Aug 10-Jan 30, 2021	Bahirdar
8	Training on COVID-19 protection practice for researchers and data collectors	Researchers, experts	Feb,1-Feb-6, 2021	Online meeting
9	Selecting participants	Researchers	Feb 30-May 2021	Bahirdar, Debretabor, Addis Ababa, Debark
10	Engaging policy makers and educationalists	Researchers, policy experts from MoE, university faculty	ongoing	Addis Ababa, Gondar, Bahirdar

We have learned a couple of crucial lessons in implementing the activities mentioned above. First, research needs the utmost patience and flexibility. At the beginning of our research project, meeting higher officials of our participating organizations was very challenging due to last-minute cancellation, re-appointing after our arrival at our research

sites, and officials' absence at their offices during our visit. Unfortunately, we did not anticipate this to happen, and we did not leave some room for flexibility in our initial research plan. However, learning from this initial encounter, we tried to accommodate unanticipated events and manage our activities despite a number of schedule disruptions.

Secondly, the initial activities, including the inception meeting and the exploratory visit, were helpful in terms of addressing any bureaucratic issues that were arising within the university settings, accessing the required data and information (e.g., where and how to get policy documents, meeting minutes, and other potential organizations we might need to visit) from MoE, and identifying potential participants for interviews. Hence, our patience to meet key individuals at the universities and at the MoE, the rapport we built with officers at different levels, and our use of personal contacts at each research site were particularly important for the successful ending of this project.

Indeed, some of our contacts and officials we met at the beginning of our project left their offices at some point. However, by the time those contacts left, we already had plenty of contacts, and we continued to meet those newcomers and build our relationships further.

5. Project outputs

In relation to this research project, a number of outputs, including published articles, publications in proceedings and conference abstracts, policy briefs, and conference presentations, were planned. Accordingly, the progress in achieving these outputs is presented in Table 4 below.

Table 4: Main project outputs

s/n	Planned outputs	Produced	expected	Remark
	-Presentations at conferences (e.g. Brownbag, Durban University annual conference presentations) - Preliminary presentation result at Bahirdar and Gondar universities	X		will continue to present in other upcoming conferences
	Research report	X		
	Technical report	X		
	Policy brief		x	Under-preparation
	Publications (peer-reviewed)		x	Under-preparation
	Abstract and proceeding publications		x	Annual research conferences of Ethiopian universities started at the month of June

As depicted in the above table, outputs related to policy briefs and publications in peer-reviewed journals are yet to be produced. We are already in discussion with the officers from IDRC on the types of journals we need to publish this evidence in. We plan to prepare and submit manuscripts for journal articles in May and June 2023. Although the peer-reviewed journals will determine the publication output, we expect a publication three to five months after submission. Furthermore, a policy brief is being prepared and is expected to be completed around the end of May 2023.

Ethiopian universities hold their annual regular research conferences around the end of May and the beginning of June of each year. We are hoping to present the findings in at least two annual conferences. As a customary practice, universities publish presented works

in the form of abstract booklets and proceedings. We expect the abstract of our work and a more extended part of the research to be published in abstract booklets and proceedings in August and September 2023.

6. Project outcomes

With the outputs described above, several outcomes were also expected. In the immediate term, for example, the presentations we made at conferences held at Bahirdar and Gondar Universities, based on the preliminary findings of this study, are expected to sensitize researchers and policymakers about the current situation of women's participation in STEM studies. Policy-makers, teachers, researchers, students, and officials at the Ministry of Education were in attendance at these presentations. The debates and question-and-answer sessions during these presentations among the participants were lively, and a few of the participants suggested re-evaluating the policies and practices related to STEM education in the higher education systems.

Some educator participants were also surprised by the evidence they saw in terms of the gender gap in STEM studies, leadership, and employment situations in the higher education system. A few faculty members expressed that they are responsible for changing this situation by providing support and dismantling barriers to women's success in the higher education system.

Upcoming presentations at different universities will enable us to reconnect with these audiences. Likewise, repeated contact with policymakers, faculty members, students, and researchers will help us strengthen researchers' capacity, strengthen the networking between researchers and policymakers, and broaden the insights of policymakers.

7. Overall assessment and recommendations

STEM education is vital for developing countries like Ethiopia, for it allows them to learn the 21st century skills and the tools they need to improve their socio-economic situations. It plays a critical role in developing nations' human capital and global competitiveness. With this understanding, the Ethiopian government has given emphasis to STEM education and the preparation of qualified nationals with credentials in STEM fields to meet the current and future needs of its economy and labor market. However, nations must ensure that such policies and practices benefit all segments of their population, including women and girls. A country's fair and just socio-economic development can only be achieved when all parts of the society meaningfully engaged.

This IDRC-supported study, therefore, examined the state of Ethiopian women in STEM studies, employment, and leadership roles in the higher education sector. The 20 years of data collected and analyzed illustrated gender disparities in university enrolment in STEM studies as well as leadership in the country's higher education sector.

The analyzed data also illustrated if and how targeted policies and specific interventions have addressed gender disparities and identified potential strategies that could improve women's participation in STEM in the country's higher education sector. This evidence will therefore be imperative for the government to re-evaluate its policies and strategies, design evidence-based policies, and achieve its overall development goals. The partnership created with IDRC, the networking among other STEM researchers in Africa and South America, and the collaboration created among the participating universities in Ethiopia have been instrumental in achieving the objectives of this project and have laid a strong foundation for future collaboration in this area.

Furthermore, this research project contributes to development in multiple ways. Firstly, the evidence generated from this study will directly affect policy and practice in relation to women's participation in STEM studies in higher education institutions in Ethiopia. Besides, as STEM underpins the 2030 Agenda for Sustainable Development, this digitized evidence from Ethiopia will serve as a benchmark for global education stakeholders to understand the status and trends of women's participation in this area and take policy actions at global, regional, and national levels. Moreover, the findings of this study will play crucial roles in achieving the sustainable development goals, improving the lives of people, and ensuring inclusive and equitable education for all through evidence-based policy actions and interventions.

Finally, this study will contribute to this area of research by adding one piece of evidence to the scientific world and inspiring STEM and education researchers to further investigate the subject matter. In particular, this study will be helpful in addressing the evidence gap in STEM and gender-related studies from Sub-Saharan Africa. Moreover, this study is expected to build internal research capacity where STEM studies in most countries in Africa rely on international collaborations.

Throughout this study, the guidance and support that the IDRC provided have been instrumental in successfully completing this project. The officers at IDRC involved in this research had the necessary expertise and skills that the project demanded. Their unreserved support and consultation were immense; they gave us constructive feedback on our reports and research processes; and they arranged conferences and workshops where we could and

would continue to disseminate our study's findings even after project completion. In general, we have had an outstanding relationship with the IDRC and its officers.

One recommendation we would like to forward to the IDRC is making assigned officers stay longer in projects. Frequent changes in assigned officers could slow down the work because both the researchers and the officers may not always agree about the project's specific direction or focus. The other challenge that we faced was related to the amount of budget withheld by the IDRC (nearly 25%) until it received the final report. This fairly large holdout compounded with the schedule and budget utilization disruption due to the war in Ethiopia and the COVID-19 pandemic, has affected the progress of the final works. Not knowing when they would be paid; some experts were reluctant to continue participating; some were struggling to complete their work on time, and some others left the project. Accordingly, we would recommend that the IDRC reconsider its holdout policies. It can lower the 25% holdout amount and focus on building stronger relationships and trust with grantees, supporting researchers closely, and being flexible based on the context.

8. The way forward

This study illustrates that women in Ethiopia are substantially underrepresented in STEM studies, leadership, and employment in higher education, although government efforts have shown some progress in addressing this gender gap. This underrepresentation of women in STEM fields deprives those fields of critical talent and slows innovation and economic development (Yang et al., 2022). Thus, more efforts need to be made to ensure that women are equally participating in STEM areas and contributing to innovation and development. Accordingly,

- As we currently lack reliable evidence in terms of cost-effective and scalable interventions that can be implemented across universities, further interventional, pilot, or evaluative studies would strengthen the current evidence and guide policies and practices.
- Further evidence on women's STEM participation rate in private higher education institutions and technical and vocational colleges is imperative, as these sectors absorb the majority of high school graduates.
- The focus of national-level policies and specific interventions by the government is mostly to enhance women's initial enrollment rates in STEM fields of study. However, access to STEM studies in higher education should be supported with retention strategies if equal outcomes between women and

men are to be achieved. Hence, policies should address access, process, and outcomes separately and equally. Doing so would also sustain gains in enrollment rates.

- Designing and implementing policy after policy alone may not be enough to close the gender gap in STEM studies, employment, and leadership in higher education. The analysis of policies and instruments implemented so far highlights the need for synergy and coordination between policy instruments and implementing stakeholders, a holistic approach to structural changes, and mechanisms to periodically evaluate and monitor through collecting evidence. Defined mandatory goals of policies combined with regulations and/or incentives are imperative to change institutional rigidity and bring coordination between policy instruments.

Declaration of Conflict of Interest
The author states that there is no conflict of interest.

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Appendix-I

Interview questions

Dear Participant: Thank you for agreeing to participate in this interview. Please elaborate on your responses when appropriate.

A) At MoE (Policy experts/directors)

Organization: _____

Position/Role: _____

Thank you in advance for your time.

1. Please tell us a bit about yourself and your background.

2. How are the policies intended to increase women's participation in STEM fields at public universities working? What's working and what's not working?

3. In designing and implementing STEM-related policies and interventions, what contributions have other stakeholders, including other ministerial offices, universities, the private sector, parents, and researchers, made?

4. Policies and strategies promote gender equality in STEM. What exactly is meant by "gender equality" in this context?

5. What do you think are the challenges that prevent achieving gender equality in STEM?

Possible follow-up:
- How did you continue to deal with those barriers?
- What advice do you give the Ministry of Education and universities to improve current practices addressing the gender disparity in STEM studies?

Other possible follow-up questions include:

- Can you tell me more about that?
- Anything else?
- Why did you feel/think that way?

Is there anything else along these lines that I have not asked about that I should have?

B) At Universities (high level Leaders)

Organization _____

Position _____

1. Please tell us a bit about yourself and your leadership role at this university.

2. What support does the university provide to attract and retain female STEM students?

3. What do you think are the main challenges that women face in pursuing STEM fields?

4. Why are there so few women faculty members and leaders at this university?

5. To what extent has the university participated in the design process of policies and interventions by the MoE?

Possible follow-up:

- How is the university trying to bring more women into the leadership arena?

- Does the university collaborate with other stakeholders in implementing interventions to address the gender gap in STEM studies, employment, and leadership?

Other possible follow-up questions include:
- Can you tell me more about that?
- Anything else?
- Why did you feel/think that way?

Is there anything else along these lines that I have not asked about that I should have?

C) At Universities (students)
University_____
Department_____

1. Please tell us a bit about yourself and your academic background.
2. What needs to happen in the STEM field to attract more women?
3. What does it take to be successful in a STEM study?
4. In your opinion and based on the experiences you have had, what are the major barriers that prevent women from joining STEM studies?
5. What kind of support does your university, college, or department provide you to succeed in your STEM studies?
6. Do you feel a sense of belonging in your STEM studies? Did you ever feel out of place? Why or why not?
7. Do you think the experience of pursuing a STEM major was different for you because of your gender identity? Why or why not?

Possible follow-up:
- How does it feel to be a woman in STEM programs of study?
- What role do you think women should play in STEM?
- What advice would you give to women aspiring to be in STEM fields? Possibly something you wished you had known when you first started?
- How did you gain an interest in STEM? Will you join graduate programs in STEM in the future?
- Were there people who influenced your decision to major in STEM? Parents? Teachers? Friends?
- Tell me what you liked or disliked about your STEM courses.

Other possible follow-up questions include:
- Can you tell me more about that?
- Anything else?
- Why did you feel/think that way?

Is there anything else along these lines that I have not asked about that I should have?

D) Students (switched from STEM to social sciences)
Warm-up questions: These questions are not designed to collect demographic information but to provide context for the interview.
.
- What was your specific STEM major?
- What is your current year at university?
- What non-STEM major are you currently pursuing?

1. Please tell us a bit about yourself and your academic background.
2. Please describe what your experiences were when you changed your major from STEM to a non-STEM field of study.
3. What situations would you think should be changed if you were given the chance to return to STEM fields of study?

4. In your opinion, do you believe it is important to get more female students into STEM education? If so, why?
5. Do you think you are better off switching from STEM to social sciences? If yes, in what ways?

Possible follow-up:
- How does your family feel about your decision to change your major to your non-STEM major? What about your peers/friends?
- When changing your major, did you consider another area of STEM? Why or why not?

Other possible follow-up questions include:
  • Can you tell me more about that?
  • Anything else?
  • Why did you feel/think that way?

Is there anything else along these lines that I have not asked about that I should have?

Appendix-II
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Survey questionnaire

</div>

Dear respondents: We, from the University of Gondar, are currently gathering data for research entitled "Breaking Barriers to Women's Participation in Science, Technology, Engineering, and Mathematics in Ethiopia. "The purpose of this study is to explore the status of women in STEM enrollment, leadership, and employment situations in Ethiopian higher education institutions. This study will also try to identify potential barriers for women to join STEM studies and assess best practices and strategies to enhance their participation in STEM. You are, therefore, kindly requested to fill out this questionnaire carefully.

All information collected in this survey will be kept with utmost confidentiality. We ought that all of the information collected will be used for academic purposes and the objectives of this research only. Thank you in Advance!

1. Demographic data
   a. Sex _____
   b. Age_____
   c. Year of study_____
   d. Department_____
   e. University_____

2. Why did you decide to study in the field of STEM? Mark or circle all that apply.
   a. It is a field in which I exceled during my studies.
   b. I was interested in the subject matter (fun and interesting).
   c. Influence of faculty members or teaching assistants
   d. Influence of an advisor or mentor
   e. It was recommended to me.
   f. Because of relatives in the field
   g. Prospects for personal development
   h. Good prospects for employment (career opportunity)
   i. Because of friends in the field
   j. Specify others_____

3. People play an important role in shaping one's career. These individuals may have supported, trained, provided advice, or endorsed you in your STEM study. Who most influenced your choice of study fields? Mark or circle all that apply.
   a. Teachers   d. career councilors
   b. Parents   e. mentor
   c. Peers   f. meetings and encounters
                                        g. others specify_____

4. Are any of these policies implemented at the university where you are enrolled? Please indicate your response

	Policies	Yes	No	Don't know
1	Gender equality plan			
2	Code of conduct (e.g., safety, sexual harassment)			
3	Offices for investigating complains			
4	Refreshment course/tutorials			
5	Career mentoring			
6	Skill development/personal development training			
7	Support service (e.g. expert support, counseling service			
8	Others specify_____			

5. Choice of career paths and cultural beliefs and stereotypes. Please indicate your degree of agreement on the following statements

No	Statements	Agree	Neutral	disagree
1	STEM is not for me; it should be for the other gender			
2	I feel like teachers do not believe in me			
3	I feel that teachers and my classmates have a negative view of me that I am being in this class			
4	I would rather more comfortable studying soft sciences such as Biology, pharmacy, or social sciences than my current field of study			
5	I would rather more comfortable studying soft sciences such as Biology, pharmacy, or social sciences than my current field of study			
6	Patriarchy is responsible for the masculine image of science fields such as engineering or Mathematics			
7	The beliefs of the society, my families, and teachers affects my pursuance of STEM studies/careers			

6. Perceived opportunities of advancement in STEM. Please indicate on your level of agreement

5 = Strongly Agree 4 = Agree 3 = Neutral 2 = Disagree 1 = Strongly Disagree

No	Statements	5	4	3	2	1
1	My current field of study makes me highly employable					
2	I have a high prospect of getting a job after graduation					
3	I may consider shifting my career to a non-STEM area					
4	I am aware of the qualifications and skills the job market requires of me					
5	I have a high prospect of professional and career advancement in my current field of study					
6	My current field of study will bring me a good level of prestige					
7	I am given the adequate training, skills, and knowledge necessary for the job market					

7. What is your level of agreement with the obstacles that you think women have to overcome in the pursuit of studies in STEM? Please indicate your level of agreement on the following statements.

No	Perceived barrier	agree	uncertain	disagree
1	Male domination in STEM fields			
2	Lack of awareness of educational opportunities in STEM fields			
3	Lack of awareness of career opportunities in STEM fields			
4	Lack of female mentors/role models			
5	Societal gender roles			
6	Perceived glass ceiling for women in STEM careers			
7	Lack of encouragement from family members			
8	Time required to become proficient in the STEM field			
9	Lack of respect for women in STEM careers			
10	Educational expenses associated with earning a STEM-related degree			
11	Lack of encouragement from teachers			

8. Have you personally experienced any of the following barriers in your path to STEM study? (Please select all that apply by circling your choices)

a. Discouragement from peers or superiors
b. Disparaging comments about your gender
c. Devaluing your achievements
d. Blatant gender bias
e. Blatant sexual harassment
f. Microaggressions
g. Feeling of inadequacy/not being good enough/
h. Other barriers (please describe) _____

9. Have you ever experienced any of the following assistance in your STEM study (please select all that apply by circling your choices)?
   a. Mentorship
   b. Sponsorship/scholarship
   c. Encouragement from peers
   d. Encouragement from superiors
   e. Encouragement from teachers
   f. Encouragement from family
   g. Support from the gender office
   h. Informal peer networking
   i. Formal networking
   j. Other assistance_____

10. Do you believe that female and male students in your fields of study treated equally where you study? Mark/circle all that apply
    a. No – consistent inequities in treatment of men and women
    b. Depends – sometimes equitable, sometimes not
    c. Yes – always equitable

11. Have you ever felt discriminated against in the assessment or evaluation of your achievements because of your: Mark/circle all that apply.
    a. Gender
    b. Age
    c. Ethnicity
    d. religion belief
    e. disability
    f. others specify_____

12. Do you think women can be as successful as men in STEM?
    a. Yes   b. No

13. Do you think STEM is equally suited for both sexes?
    a. More suited for men.   b. More suited for women   c. Equally suited for both men and women

14. Would you recommend others who are not yet in STEM studies to join your field of study or other STEM related fields of study?
    a. Yes, I would recommend them   b. No, I wouldn't recommend them

15. Studies showed that women's enrollment in STEM fields of study at universities is very low compared to men's. What do you think are the reasons for this?

    _____
    _____
    _____
    _____

16. From your point of view, what strategies do you think would bring and retain more girls to STEM studies?

    _____
    _____
    _____

Appendix-III

Guidelines for reviewing the policy and strategy documents pertaining to women and STEM in higher education institutions of Ethiopia.

	ESDP-I	ESDP-II	ESDP-III	ESDP-IV	ESDP-V	Other policy documents (ETP, GTP,…..)
Central objective/rational						
intentions						
Indicators/expected outcomes						
Gender equity targets						
context						
Performance measures						
Implementation strategy/specific instruments						
stakeholders						

Appendix IV-consent form
                    Consent form

Title of Study: ***Breaking Barriers to Women's Participation in Science, Technology, Engineering and Mathematics in Ethiopia***
Principal Investigator name: Gebeyehu Begashaw

Address: University of Gondar

E-mail: gebeyehu_2006@yahoo.com

Background:

You are being invited to take part in a research study on ***Breaking Barriers to Women's Participation in Science, Technology, Engineering and Mathematics in Ethiopia***. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. Please take the time to read the following information carefully. Please ask the researcher if there is anything that is not clear or if you need more information.

The purpose of this study is:

- To explore the status and trends of women in STEM enrollment, leadership, and employment situations in Ethiopian higher education institutions.

- To identify and assess, through an intersectional analysis, the barriers for women to participate in STEM studies, leadership, and employment in Ethiopian higher education institutions.

- To identify what best practices are available and what policy changes at both the national and university level could be made to increase the participation of women students, researchers, and leaders in STEM fields in higher education institutions in Ethiopia.

Study Procedure:

Your expected time commitment for this study is 40 to 50 minutes.

Risks: An investigator will ask you to answer a series of structured questions from a questionnaire. All your answers will be coded and kept confidential. Apart from the researcher or interviewer, nobody else will have access to the answers you provided to the questionnaire. You may terminate your participation in this study at any time if you choose.

Benefits: There will be no direct benefit to you from your participation in this study. However, we hope that the information obtained from this study may help policymakers, researchers, and universities design policies and measures that could enhance the participation of women in STEM studies, employment, and leadership at higher education institutions.

Confidentiality: Please do NOT write any identifying information on your questionnaire. Your responses will be anonymous. All your responses will be kept anonymous at all times. Every effort will be made by the researcher to preserve your confidentiality, including the following: Assigning code names or numbers for participants that will be used on all researcher notes and documents.

Voluntary Participation: Your participation in this study is voluntary. It is up to you to decide whether or not to take part in this study. If you do decide to take part in this study, you will be asked to sign a consent form. If you decide to take part in this study, you are still free to withdraw at any time without giving a reason. This will not affect the relationship you have with the researcher.

Costs to Subject: There are no costs to you for your participation in this study

Compensation: There is no monetary compensation to you for your participation in this study.

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Consent

</div>

By signing this consent form, I confirm that I have read and understood the information about the study and have had the opportunity to ask questions. I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason or incurring any cost. I understand that I will be given a copy of this consent form. I voluntarily agree to take part in this study.

Participant X---

Participants Signature _____date_____

Researcher signature_____date_____

Contact information

This research has been reviewed and approved by the ethical review board of the University of Gondar. If you have any further questions or concerns about this study, please contact: Gebeyehu Abate at gebeyehu_2006@yahoo.com or ask the data collector to put you in contact with the researcher and/or close supervisors.

What if I have concerns about this research?

If you are worried about this research or if you are concerned about how it is being conducted, you can contact the research and technology vice president office or the director of the research office of the University of Gondar.

Address: University of Gondar
Vice president for research and technology transfer
        President building
Appendix V: ethical clearance

University of Gondar
Vice President Research & Community Service
Gondar, Ethiopia

R. No.- V/P/RCS/05/ _2010_ /2020

Date:- _1st June_ 2020

To:- Mr. Gebeyehu Begashaw
University of Gondar

Subject: - **Ethical Clearance**

Your research project proposal entitled **"Breaking Barriers to women's participation in science, technology, Engineering and mathematics in Ethiopia."** has been reviewed by the Institutional Ethical Review Board of University of Gondar for its Ethical soundness, and it is found to be ethically acceptable.

Thus, the Research and Community Service Vice President Office has awarded this Ethical Clearance for the above stated study to be carried out by **Mr. Gebeyehu Begashaw** as Principal Investigator and **Mr. Aysheshim Terefe, Dr. Danaiel Tsehay, Mrs. Tinsae Berihun,** as Co-Investigator as of **June 4th, 2020.**

These investigators are expected to submit their research progress report to the Vice President for Research and Community Service Office of the University of Gondar.

Best Regards

Meresha Chanie Kebede (Professor)
Vice President Research and
Community Service

C.C.
Research and publication Directorate
Institutional Review Board
University of Gondar

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