Ministry of Education
Federal Democratic Republic of Ethiopia

Japan International Cooperation Agency
(JICA)

Federal Democratic Republic of Ethiopia

Project for Mathematical Understanding for Science and Technology
(MUST)

Project Completion Report
(Period 2)

August 2023

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(MUST)
in the Federal Democratic Republic of Ethiopia

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(Period 2)

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ACRONYMS AND ABBREVIATIONS

AAEB	Addis Ababa Education Bureau
ACT1	Achievement Test No.1
ACT2	Achievement Test No.2
A-D-E-E	Activity-Definition-Example-Exercise
CDID	Curriculum Development and Implementation Directorate
CI	confidence interval
COVID-19	Corona Virus Infectious Disease, emerged in 2019
CPD	Continuous Professional Development
CTE	College of Teacher Education
df	degree of freedom
DSA	Daily Subsistence Allowance
EC	Ethiopian calendar
EMIS	Education Management Information System
EPRMD	EMIS, Planning and Resource Mobilization Directorate
ESDP	Education Sector Development Program
ETB	Ethiopian Birr
F	female
G	Grade
IDCJ	International Development Center of Japan Inc.
JCC	Joint Coordinating Committee
JDS	Japan Development Service Co., Ltd.
JICA	Japan International Cooperation Agency
JPY	Japanese Yen
KG	kindergarten
KRC	Koei Research & Consulting Inc.
LAMS	Project for Capacity Development for Improving Learning Achievement in Mathematics and Science Education
M	male
M&E	Monitoring and Evaluation
MLC	Minimum Learning Competency
MNS	MUST non-pilot school
MoE	Ministry of Education
MPS	MUST pilot school
MSIC	Mathematics and Science Improvement Center
MUST	Project for Mathematical Understanding for Science and Technology
NEAEA	National Educational Assessment and Examinations Agency
No	number
PDM	Project Design Matrix
PO	Plan of Operation
R/D	Record of Discussion
REB	Regional Education Bureau
SD	standard deviation
SIP	School Improvement Program
SMASEE	National Pilot Project for Strengthening Mathematics and Science Education in Ethiopia
SNNPR	Southern Nations, Nationalities, and Peoples' Region
TDP	Teacher Development Program
TELDA	Teachers and Educational Leaders Development Administration
TELDD	Teachers and Educational Leaders Development Directorate
TLM	teaching and learning material
ToT	Training of Trainers
TPR	textbook to pupil ratio

U	Unit
USD	US Dollar
UT	Unit-End Test
VP	viewpoint
VSOC	Vision & Spirit for Overseas Cooperation Co., Ltd.
WS	workshop

EXECUTIVE SUMMARY

1 FRAMEWORK OF THE PROJECT

MUST (Project for Mathematical Understanding for Science and Technology) is a technical cooperation project jointly implemented by the Federal Ministry of Education of Ethiopia (MoE) and the Japan International Cooperation Agency (JICA). Its first period ran from March 2019 to July 2021, and the second period started in August 2021 and was completed in August 2023.

Period 1 originally aimed at developing Lesson Support Materials for primary school students and teachers (G1-G8) to supplement the existing textbooks and teacher's guides. Later MoE changed its policy and requested JICA to assist MoE to assure the quality of the curriculum and textbooks for secondary schools (G9-G12). JICA accepted this new request and modified PDM accordingly. In the revised framework, five outputs were to be achieved by the Project:

Output 1: Quality of the mathematics curriculum documents (flowcharts, MLCs, and syllabi) is assured;
Output 2: Technical recommendations, based on the situational analysis of classroom practices, are incorporated to Grades 9-12 textbook editing strategies and M&E;
Output 3: The capacity in developing Grades 1-8 mathematics teaching materials are improved through technical WS;
Output 4: The quality of Grades 9-12 textbook contents is improved; and
Output 5: Strategies for improving the utilization of Grades 9-12 textbooks are proposed based on monitoring and evaluation.

Among the five outputs above, the central activities of Period 2 were related to Output 4 and Output 5.

2 REVISION OF THE PROJECT DESIGN MATRIX (PDM)

The first version of PDM, dated October 19, 2018, specified that "developing Lesson Support Materials for students and teachers" for "Grade 1-8 mathematics" was the main output of the project. In November 2019, CDID made a strong request to JICA to cover Grades 9-12 as well. Further in October 2020, CDID changed its policy on curriculum reform and proposed to shift the target of MUST from Grades 1-8 to Grades 9-12 and its main output from "Lesson Support Materials" to "quality assurance of the new curriculum, textbooks and teacher's guides." MoE and JICA agreed with the modifications and signed the revised PDM on February 26, 2021. The revised PDM was further revised again by specifying objectively verifiable indicators. The second revised PDM was signed on September 26, 2022.

3 PROJECT INPUTS

From the JICA side, fourteen experts have been assigned to this project. Total person-months of Period 2 were 55.20. From the MoE side, 13 experts have been assigned as counterpart experts to work for MUST. MoE has provided office space for MUST throughout Period 2.

4 PROJECT ACTIVITIES

Outputs, Activities and Achievements

MUST has pursued to assist CDID in assuring ***the quality of curriculum documents for G1-G12 and textbooks and teacher's guides for G9-G12*** in mathematics. It has implemented various activities as follows.

Activities Related to Output 1

The main activity for Output 1 was to improve the curriculum documents (flowcharts, MLCs and syllabi). A team of mathematics experts convened from four universities developed the documents. The JICA Expert Team reviewed them and submitted their comments to CDID in March 2021. Severe time constraint, however, prevented the full incorporation of the comments into the documents.

Activities Related to Output 2

Activities for Output 2 were to conduct a situational survey and to make technical recommendations. The MUST project conducted a G9-G12 situational survey on April 19-24, 2021, targeting six secondary schools selected from Addis Ababa. The survey revealed: 1) Students' performances are not satisfactory; 2) the current textbooks are too difficult for most students; and 3) students do not bring their textbooks to class because they are voluminous and heavy to carry and/or not used in the class. Furthermore, 4) more than one-third of the teachers cannot carry out the annual teaching plan as planned; and 5) several teachers emphasized the importance of reducing the contents, as well as aligning the difficulty level of the textbook to students' actual competency level.

Given those findings, the JICA Expert Team proposed to revise the draft textbooks stepwise with respect to five viewpoints (directions) [from easy/simple to difficult/complicated]:

1) Correction of mistakes;
2) Improvement in layout, mathematical expressions, terms, graphs, figures, etc.;
3) Improvement of the structure of Activity-Definition-Example-Exercise by adopting the essence of the standard lesson flow (particularly applying the "1 topic, 1-2 pages" principle);
4) Modification of problems at the right level of students' learning; and
5) Improvement/enrichment of the contents.

Activities Related to Output 3

Activities for Output 3 were to develop sample textbooks and teacher's guides for Grades 1, 4, 7 and to hold technical workshop for regional textbook developers. The JICA Expert Team in 2019 started developing Lesson Support Materials for Grades 1, 4 and 7 under the old PDM. Though this task was no longer included in the new PDM, the JICA Expert Team nonetheless continued their development until July 2021 and submitted the completed textbooks and teacher's guides to CDID and JICA as the references for regional G1-G8 textbook development and as the main output prescribed in the initial PDM.

On request by CDID, the JICA Expert Team conducted a technical workshop on April 26-28, 2021, for G1-G8 textbook developers in regions. It aimed at familiarizing them with the whole process of textbook development and how the editing policy should be established. Due to COVID-19, JICA experts could attend the workshop held in Adama only online from Addis Ababa or Japan. According to a post-workshop survey done in November and December 2022, the participants came to clearly realize that the current textbooks were too difficult for students. They all answered that the workshop contents were beneficial for their textbook development.

Activities Related to Output 4

The main activity for Output 4 was to conduct workshops for Textbook Developers to improve draft textbooks and teacher's guides for G9-G12. Between October 2021 and January 2023, MUST held seven workshops with them to revise and improve the drafts stepwise according to the five viewpoints explained above. The Textbook Developers very positively evaluated their whole experiences, particularly accepting the benefits of "unitized" textbooks to improve students' achievement in mathematics.

Activities Related to Output 5

Activities for Output 5 were to conduct M&E activities of piloting and to draw up strategies for improving the utilization of Grades 9-12 textbooks through the M&E. During the nine-month period from September 2022 to May 2023, MUST carried out five main activities at selected secondary schools to monitor the piloting, evaluate the effect of the new textbooks, and formulate strategies for improving the utilization of the new textbooks. The five main activities are:

1) Induction training and follow-up activities (including Subject Teachers Meetings)
2) Achievement Test No.1
3) Lesson observation and introduction of Rubric (lesson self-evaluation)
4) Unit-End Tests
5) Achievement Test No.2

Induction training was conducted in September-October 2022 for mathematics teachers at respective three MUST pilot schools, to promote understanding of the "unitization" principle (one topic per lesson) incorporated in the new textbooks and the concept of A-D-E-E structured lesson. The JICA Expert Team particularly emphasized that the teacher should spend 20 minutes for his or her explanation and 20 minutes for students' independent activity (20-20 principle) and that students should always work on one evaluation item in each lesson.

Lesson observation was conducted to monitor the practice of structured teaching (A-D-E-E) using the draft new textbooks and to provide feedback to the teachers as well as to the Textbook Developers. The main findings from lesson observation were: 1) about half teachers gave more than ten minutes for students to solve an evaluation item individually; 2) students' achievement was generally low; 3) majority of the students were very passive; and 4) not all students brought textbooks (photocopies) to the class in spite of teacher's instruction.

The subject teachers meeting was planned as part of follow-up support for the teachers of the pilot schools. However, it turned out that no school holds subject teachers meetings regularly. Nonetheless, the JICA Expert Team managed to hold one trial meeting at Kokebe Tsibah Secondary School, and three meetings at Abyot Kirs Secondary School.

Partly to cope with this constraint, the JICA Expert Team developed the "Rubric" in February 2023 for teachers and observers to evaluate the A-D-E-E lessons qualitatively. For those teachers motivated to improve their lessons, self-reflection using the Rubric may be effective. However, it was difficult to make unmotivated teachers aware of their shortcomings. To encourage those teachers to conduct self-reflection, we may need to give them feedback from the school leaders and supervisors.

MUST conducted two Achievement Tests during the piloting of G9 and G10 textbooks. Achievement Test No.1 was conducted at the end of October 2022 and Achievement Test No.2 was conducted six months later in April 2023. Statistical analyses indicate that, with both G9 and G10, students in MUST pilot schools have improved their performance more than those in MUST non-pilot schools during the piloting.

Unit-End Tests were conducted when each Unit was completed with G9 and G10. Right after students learnt a certain Unit, the Unit-End Test was given to them to compare the scores between MUST pilot schools and MUST non-pilot schools. Three out of four Unit-End Tests, two for G9 and one for G10, showed statistically significant differences between the students of pilot schools and non-pilot schools. Given the results of Achievement Tests and Unit-End Tests, we conclude that the new textbooks and the new pedagogy have contributed to the improvement of academic achievement.

As the draft strategy to improve students' learning achievement, a package of resource materials entitled "A-D-E-E Structured Math Lessons for Ethiopian Students' Learning Improvement and Its Good Practices from MUST Pilot Schools" was compiled and shared with REBs in July 2023.

5 ACHIEVEMENT OF PROJECT OBJECTIVES

MUST has made three main achievements:

1) Successful introduction of "unitization" (first of its kind in Ethiopia);

2) Verification that the new textbooks and teaching method can improve students' achievement in mathematics; and

3) Development of a set of resource materials to facilitate teachers to conduct A-D-E-E lessons.

Following is a summary of project achievement of respective goals, purposes and outputs evaluated with respect to the Objectively Verifiable Indicators.

Super Goal, "The learning performance in mathematics is improved," will be verified 10 years later.

Overall Goal, "Educational activities based on the new mathematics curriculum are promoted," have been achieved with respect to one indicator while two others will be verified 3 years later.

Project Purpose, "Educational activities based on the new mathematics curriculum are introduced," has been achieved with respect to all three indicators.

Output 1, “Quality of the mathematics curriculum documents (flow charts, MLCs, and syllabi) is assured,” has been achieved.

Output 2, “Technical recommendations, based on the situational analysis of classroom practices, are incorporated to Grades 9-12 textbook editing strategies and M&E,” has been achieved.

Output 3, “The capacity in developing Grades 1-8 mathematics teaching materials are improved through technical WS,” has been achieved.

Output 4, “The quality of Grades 9-12 textbook contents is improved,” has been achieved with respect to four indicators.

Output 5, “Strategies for improving the utilization of Grades 9-12 textbooks are proposed based on monitoring and evaluation,” has been achieved with respect to two indicators while one indicator has been partially achieved.

The project’s achievements are also evaluated with respect to the OECD DAC evaluation criteria.

Relevance is very high. MUST project as a technical cooperation project was a right vehicle to provide technical support MoE needed in its curriculum reform.

Coherence is very high. Curriculum and textbook development are two main components of JICA’s priority areas for assistance in education. MUST has been a nice complement to UNICEF’s general assistance to Ethiopia’s curriculum reform. MUST has also referred to other development partners’ experiences and results in applying the A-D-E-E structure to the Ethiopian context.

Effectiveness is high. At the three pilot schools, MUST has achieved the Project Purpose. However, this was possible only because MUST provided photocopies of the new textbooks to the schools when MoE was unable to deliver the new textbooks as planned. Some activities tried at the pilot schools turned out to be difficult due to systemic problems. Adjustments have been made accordingly but they have to be tested for their practicability.

Efficiency is high. MUST project as a whole proved very cost efficient, achieving the Outputs as specified in the PDM without much additional input even in the very hard and irregular situations because of COVID-19 and insecurity in the north. Nonetheless, insufficient personnel input from MoE made it difficult for the JICA experts to provide effective technical support and, due to the complete revision of PDM, sample Lesson Support Materials for G1, G4 and G7 could not be fully utilized in Period 2.

Impact can be high. After MUST project is finished, it is expected that the Overall Goal can be achieved throughout Ethiopia if MoE provides the textbooks as planned and the REBs properly train the math teachers utilizing the “A-D-E-E Package” prepared by MUST. Once the Overall Goal is achieved, the Super Goal, “The learning performance in mathematics is improved,” is highly likely to be achieved, too.

Sustainability is neither high nor low. The most critical components should be 1) budget for textbook printing, 2) budget for teachers’ training, 3) technical support for teachers’ training and continuous professional development, and 4) Ethiopian resource persons. Since initial budget has been secured for printing, additional budget is expected to come soon. REBs are willing to conduct necessary teachers’ training but budget is not sufficient. They need to come up with cost-effective activities possible within their own resources. Technical support can be partially provided by a new JICA advisor succeeding MUST. Three groups of resource persons (teachers, education officials and the Textbook Developers) are available for the dissemination of the new concepts. However, budget to mobilize them and the trainees would be the main constraint.

6 STEPS FORWARD

There remain a few new tasks to be tackled by MoE in the coming years. With the new, improved textbooks and teacher’s guides in hands, what tasks should MoE tackle next?

Distributing Textbooks

Since all previous textbooks of all subjects must be replaced with the new textbooks all at once in September 2023, MoE needs a considerable amount of budget and time to accomplish it. In view of

various constraints, however, it would be a realistic approach to provide the new textbooks gradually in a few years. If MoE pursues the ratio of one textbook to four students (1:4 TPR), it should be accepted as a temporary measure, but printing of additional copies must be pursued by all means.

Implementing the MUST Outputs Other Than Textbooks

MUST project has produced some notable outputs other than the textbooks and teacher's guides, which are the Rubric and the A-D-E-E Package. Their wide utilization should be promoted and supported by MoE.

Changing Teaching Methods

Two characteristics of the conventional teaching methods seem particularly detrimental as far as judged from the lessons observed by MUST. One is that teachers write everything on the blackboard, without referring the students to the textbook. Two is that teachers do not use the time given to the students' independent activity so effectively. To cope with the first problem, teachers should prepare board writing plans. The "A-D-E-E Package" includes some training materials for that purpose. The second problem may not be difficult to overcome. Training may be the only and best way to make the teachers aware of the problem and once they know the problems, they can change their practices with the help of specific hints about teaching techniques. The Rubric can help the teachers recognize such shortcomings in their teaching style and try to overcome them.

Institutionalizing the A-D-E-E Structure

MUST has proved that the new textbooks can improve students' performance when combined with the new teaching method of A-D-E-E structure. If this evaluation holds even after the full implementation of the new textbooks in 2023/24, MoE may consider institutionalizing the A-D-E-E structure in Ethiopia.

The first step necessary for its institutionalization may be to declare in the Curriculum Framework that the A-D-E-E structure should be adopted, in principle, to all subjects of all grades. It would be crucially important to adopt the structure to primary school math textbooks, too.

Making Textbooks Slimmer

Students do not like to bring thick and heavy textbooks to school. This is one main reason for the low math achievement of the Ethiopian students. The new mathematics textbooks for G9 to G12, however, are thicker than the previous textbooks. To make the textbooks slim, the curriculum framework needs to be revised to reduce the total number of annual lesson periods (156) to a more realistic one (around 120). The syllabi should be thoroughly revised to make the contents fit into 120 or so lesson periods. The textbooks themselves can be made slim by reducing unnecessary spaces. Potential benefits of slimmer textbooks are enormous. It would be highly recommended for MoE to spend significantly more time on deliberation of the Curriculum Framework and syllabi and on development of textbooks when they are to be revised next time.

For teachers, MUST would strongly suggest utilizing the List of Contents as a partial and tentative remedy to overcome the problems of the thick textbooks.

1 OUTLINE OF THE PROJECT

1.1 Country for Implementation

This project has been implemented in the Federal Democratic Republic of Ethiopia.

1.2 Project Title

The title of the project is: The Project for Mathematical Understanding for Science and Technology (MUST).

1.3 Project Period

The duration of this project was divided into two periods. The first period, Period 1, started in March 2019 and ended in June 2021. The second period, Period 2, started in August 2021 and ends in August 2023.

1.4 Background

To facilitate the rapid industrial development by providing better human resources, Ethiopia has long emphasized mathematics and science education as envisaged in its Education Sector Development Program IV (ESDP IV) (2010/11~2014/15) and Education Sector Development Program V (ESDP V) (2015/16~2019/20).

JICA has supported the Ethiopian government's education policy with three major projects:

- Project for Strengthening Mathematics and Science Education in Ethiopia (SMASEE) [2011~2014]
- Project for Capacity Development for Improving Learning Achievement in Mathematics and Science Education (LAMS) [2014~2017]
- Monitoring and Evaluation for Strengthening Mathematics and Science Education in Ethiopia [2014~2017]

SMASEE and LAMS both targeted mathematics and science (biology, chemistry, physics) for Grades 7 and 8. They successfully produced their expected outputs but it still requires substantial efforts to make the students' academic performances better. The Ministry of Education (MoE) thus requested JICA to implement another project as a sequel to improve mathematics achievements by primary school students (G1~G8) further. MUST was thus formulated to accommodate this request.

At the beginning, the project was aimed at developing Lesson Support Materials both for students and teachers of G1 to G8 to supplement the existing textbooks and teacher's guides, on the basis of analyses of the problems facing Ethiopian primary school students. It was intended that the Lesson Support Materials thus developed would be adopted by MoE as the prototype curriculum and teaching and learning materials.

This plan was later cancelled, however. In October 2020 MoE changed its policy on curriculum reform from "assistance" to "self-reliance": MoE would develop the curriculum and textbooks with its own resources, not asking developing partners to develop them on their behalf. Accordingly, MoE's request to JICA was also changed from developing Lesson Support Materials to assisting MoE to assure the quality of the curriculum and textbooks to be developed on their own. In addition, the target grades were to be extended to cover G1~G12 to ensure consistency in the curriculum development. At the same time, MoE stressed that the constitution stipulates that G1~G8 should be responsibility of Regional States and MoE would not touch on the textbook development of those grades: only G9~G12 are under MoE's direct jurisdiction. Given those fundamental shifts in assumptions, JICA had to frame the whole project again. Since JICA is conditioned to cooperate with the Federal Government and not directly with Regional State Governments, it was decided and agreed upon to change the target grades from G1~G8 to G9~G12.

After a series of discussion between MoE and JICA, a new set of Record of Discussion (R/D), Project

Design Matrix (PDM) and Plan of Operation (PO) was signed in February 2021, near the end of Period 1. MUST Period 2 has been implemented basically within this new revised framework.

1.5 Goals and Objectives

According to the final versions of R/D and PDM, this Project has following goals and objectives:

Super Goal: The learning performance in mathematics is improved

Overall Goal: Educational activities based on the new mathematics curriculum are promoted

Project Purpose: Educational activities based on the new mathematics curriculum are introduced

See Project Design Matrix (revised) (Appendix 2).

1.6 Outputs and Activities

Five outputs are to be achieved by the Project. Among them, the last output, Output 5, is the task to be carried out jointly with the long-term JICA Expert stationed at MoE.

***Output 1*:** Quality of the mathematics curriculum documents (flowcharts, MLCs, and syllabi) is assured

***Output 2*:** Technical recommendations, based on the situational analysis of classroom practices, are incorporated to Grades 9-12 textbook editing strategies and M&E

***Output 3*:** The capacity in developing Grades 1-8 mathematics teaching materials are improved through technical WS

***Output 4*:** The quality of Grades 9-12 textbook contents is improved

***Output 5*:** Strategies for improving the utilization of Grades 9-12 textbooks are proposed based on monitoring and evaluation

For respective Outputs, several activities are specified for the Project to carry out. They are as follows:

Activities for Output 1:

1. Make a technical support plan
2. Conduct (online) technical support of the curriculum materials (flow charts, MLC, and syllabi) for Grades 1-12
3. Revise and finalize the curriculum materials
4. Conduct a validation workshop for the curriculum materials

Activities for Output 2:

1. Conduct a situational survey
2. Make concrete recommendations during the development process to improve Grades 9-12 textbook editing

Activities for Output 3:

1. Create a technical support plan for REB textbook writers
2. Develop Grades 1, 4, 7 teaching and learning material samples for the main purpose of capacity development for Grades 1-8 REB textbook writers
3. Conduct workshops for REB textbook writers to develop the capacity to write textbooks

Activities for Output 4:

1. Conduct workshops for textbook developers to improve draft Grades 9-12 textbooks and teachers guide
2. Provide further technical support to improve draft Grades 9-12 textbooks and teachers guide

Activities for Output 5:

1. Select MUST pilot schools and MUST non-pilot schools to verify the learning improvement mechanism
2. Conduct induction training to MoE pilot schools in CDID/MoE-organized workshops

3. Conduct pre-pilot training for Grades 9-10 math teachers at MUST pilot schools
4. Provide special support to Grades 9-10 math model teachers at MUST pilot schools
5. Conduct achievement tests and unit tests at MUST pilot schools and non-pilot schools
6. Conduct lesson observation at MUST pilot schools and non-pilot schools
7. Compile the results of MUST M&E activities
8. Conduct a nation-wide workshop to share the MUST/MoE pilot experiences among stakeholders
9. Collect data on Grades 9-12 textbook usage at the classroom level through M&E
10. Make strategies to improve the learning achievement of students using Grades 9-12 textbooks at the classroom level

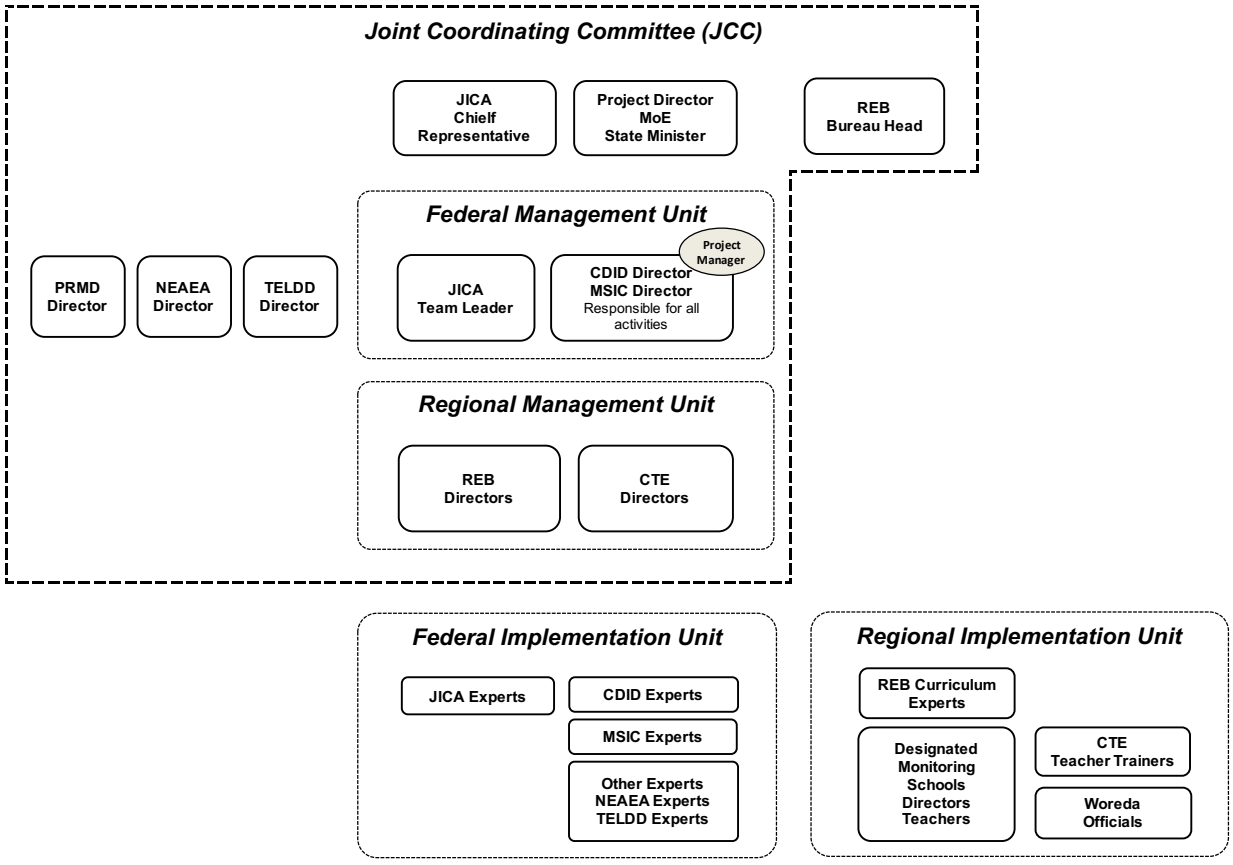
1.7 Executing Agencies

Following agencies have worked for this Project as the Ethiopian executing agencies:

- Curriculum Development and Implementation Directorate (CDID) [Main counterpart]
- Mathematics and Science Improvement Center (MSIC)
- Educational Planning and Resource Mobilization Directorate (EPRMD)
- Teachers and Educational Leaders Development Directorate (TELDD)
- National Educational Assessment and Examinations Agency (NEAEA)
- Regional Education Bureaus (REBs)

1.8 Organizational Structure for Implementation

The revised structure for the implementation of this Project is shown in Figure 1.1. It is organized at the federal and regional levels.



Source: Minutes of Meeting between Japan International Cooperation Agency and the Ministry of Education of the Federal Democratic Republic of Ethiopia for Amendment of the Record of Discussions on the Project for Mathematical Understanding for Science and Technology (MUST), 26 February 2021, Annex 5.

Figure 1.1 Project Implementation Structure (Revised)

1.9 Changes in CDID/MoE's Plan for Textbook Development

The current curriculum reform by MoE started in earnest in late 2019. Since then, CDID/MoE has made a series of changes in their reform implementation plan to adapt to the fluid situation. As far as MUST is concerned, two aspects are of particular importance: 1) target grades and timing of piloting; and 2) secondary-level textbook developers. Table 1.1 below summarizes how those two aspects evolved during the three-year period of 2019~2022. MUST has had to adjust its course to those frequent changes in its project framework.

Table 1.1 Changes in CDID/MoE's Plan for Textbook Development

<table>
<tr><th>Date</th><th>Piloting Plan</th><th>Secondary-Level Textbook Developers</th></tr>
<tr><td>Sept 2019</td><td>- Piloting with a few selected grades
- Start in Sept 2020</td><td>- Math Panel members (?)</td></tr>
<tr><td>Feb 2020</td><td>- Piloting in three stages:
KG, G1, 4, 7, 9, 11 Start in Sept 2020
G2, 5, 8, 10, 12 Start in Sept 2021
G3, 6 Start in Sept 2022</td><td>- Math Panel members (?)</td></tr>
<tr><td>Oct 2020</td><td>- No piloting
- All grades start full implementation in Sept 2021</td><td>- Math Panel was disbanded
- To be outsourced to some outside body</td></tr>
<tr><td>Nov 2020</td><td></td><td>- Center of Excellence was commissioned to develop curriculum documents and secondary-level textbooks</td></tr>
<tr><td>July 2021</td><td></td><td>- Center of Excellence selected and appointed textbook developers</td></tr>
<tr><td>Aug 2021</td><td>- Revised plan
<table>
<tr><th></th><th>EC2014 (2021/22)</th><th>EC2015 (2022/23)</th><th>EC2016 (2023/24)</th></tr>
<tr><td>G1-7</td><td>Pilot</td><td>Full implementation</td><td>General evaluation</td></tr>
<tr><td>G8</td><td>-</td><td>Full implementation</td><td>General evaluation</td></tr>
<tr><td>G9-10</td><td>Pilot</td><td>Full implementation</td><td>General evaluation</td></tr>
<tr><td>G11</td><td>Full implementation</td><td>Full implementation</td><td>General evaluation</td></tr>
<tr><td>G12</td><td>-</td><td>Full implementation</td><td>General evaluation</td></tr>
</table></td><td></td></tr>
<tr><td>Nov 2021</td><td>- For G9 and G10, piloting starts in Jan 2022
- With only Unit 1
- Other Units will be finalized and distributed later</td><td></td></tr>
<tr><td>Feb 2022</td><td>- Piloting of G9 and G10 postponed until Sept 2022
- Revised plan
<table>
<tr><th></th><th>EC2014 (2021/22)</th><th>EC2015 (2022/23)</th><th>EC2016 (2023/24)</th></tr>
<tr><td>G1-7</td><td>Pilot</td><td>Full implementation</td><td>General evaluation</td></tr>
<tr><td>G8</td><td>-</td><td>Full implementation</td><td>General evaluation</td></tr>
<tr><td>G9-10</td><td>-</td><td>Pilot</td><td>Full implementation</td></tr>
<tr><td>G11-12</td><td>-</td><td>-</td><td>Full implementation</td></tr>
</table></td><td></td></tr>
<tr><td>Sept 2022</td><td>- Piloting starts with G9 and G10 as scheduled</td><td></td></tr>
</table>

1.10 Trip Bans Imposed on the JICA Expert Team

During the project implementation period of March 2019~August 2023, the JICA Expert Team met with three trip bans imposed by JICA. One was very long and two others lasted a few months each. This was quite unusual and had significant impact on the project operation. The three bans are summarized in Table 1.2.

Table 1.2 Trip Bans Imposed on the JICA Expert Team

	Duration		Reason
1	Mar 2020~Dec 2020	About 10 months	COVID-19
2	Mar 2021~July 2021	About 4 months	COVID-19 and general election
3	Nov 2021~Feb 2022	About 4 months	Security situation in the north (state of emergency)

2 REVISION OF THE PROJECT DESIGN MATRIX (PDM)

2.1 Original PDM and Subsequent Changes in Project Framework

First Version of PDM

The first version of PDM, dated October 19, 2018, specifies "developing Lesson Support Materials for students and teachers" for "Grade 1-8 mathematics" are the main output of the project. The MUST project started its operation in March 2019 as prescribed in this PDM.

It should be noted that the MoE launched its comprehensive curriculum and textbook reform in 2019 almost simultaneously with the initiation of the MUST project. Thus, it was strongly expected that the MUST outputs would eventually be adopted as the official textbooks and teacher's guides for Grades 1-8 strictly based on the newly developed math curriculum. As the initial step, MoE appointed 12-member Math Panel in December 2019 and assigned them to prepare a position paper about the curriculum reform and the curriculum-related documents.

Initially, it was planned to implement the reform by piloting the newly revised textbooks in three years. The first year was scheduled to start in September 2020, targeting KG (kindergarten), Grades 1, 4, 7, 9 and 11 as the pilot grades. To align with this plan, the JICA Expert Team for MUST adjusted its overall work schedule and started to develop Lesson Support Materials for Grades 1, 4 and 7, following the framework specified in the PDM.

Additional Request by CDID and Planned Revision of PDM

In November 2019, CDID Director strongly requested JICA to cover Grades 9-12 as well and carry out a baseline survey of those grades to analyze their academic performances in mathematics. JICA seriously considered this additional request and started preparation for the revision of the PDM and Record of Discussion (R/D) to accommodate it. After a series of discussions with MoE, the revised documents were scheduled to be signed in April 2020.

COVID-19 and Sudden Personnel Change

In February 2020, however, COVID-19 broke out in Ethiopia and all JICA Experts for MUST had to return to Japan by the end of March. On April 8, Prime Minister Abiy declared the state of emergency and all activities at MoE and by Math Panel were strictly suspended. This untimely incident practically stopped all the MUST activities in Ethiopia and the signing of the revised PDM and R/D was indefinitely postponed.

To make the situation more difficult, there was a sudden personnel change at MoE in October 2020, with new Director of CDID appointed. The JICA Expert Team for MUST thus took some extra time to resume smooth cooperation with CDID as before.

New Policy of MoE

Following the organizational reshuffle, in October 2020, MoE was quick to announce two important policy changes in the on-going curriculum reform process. First, it disbanded the Math Panel, contracting out the assigned work to an outside subcontractor. Second, it would not ask JICA to develop the Lesson Support Materials but to support MoE to assure the quality of new curriculum, textbooks and teacher's guides. In addition, it made it clear that, under the constitution, G1-G8 teaching materials are strictly a responsibility of Regional States, and that CDID has no authority to dictate the regions' work. It can only deal with G9-G12 when teaching materials are concerned. Those changes have obliged JICA to modify the framework of MUST project accordingly.

First Revision of PDM

Since October 2020, JICA and MoE had had a series of discussions on how to revise the PDM and other project documents. They finally agreed on and signed the revised PDM and Record of Discussion on February 26, 2021. Under the new framework, the target grades were changed from G1-G8 to G9-G12. The main activity for the project was shifted from "developing Lesson Support Materials" to "providing quality assurance of the newly developed curriculum, textbooks and other materials/documents." The project outputs were also replaced with a totally different set. MUST Period 2 operations started within

the framework of this first revised PDM.

Second Revision of PDM

The revised PDM nonetheless left some parts tentative. The case in point was objectively verifiable indicators, to be used to measure, particularly, the achievement level of the five outputs. A series of discussion once again took place between JICA and the JICA Expert Team for MUST and, subsequently, between JICA and MoE. The second revised PDM, along with R/D, was finally signed on September 26, 2022.

2.2 Comparison of PDMs

Table 2.1 summarizes main differences of the three versions of PDM.

Table 2.1 Main Differences of the Three Versions of Project Design Matrix

	First Version	Revised Version	Second Revised Version
Dated	October 19, 2018	December 16, 2020	September 26, 2022
Version No.	1.0	3.0	4.0
Implementing Agency	Mathematics and Science Improvement Center (MSIC) and other institutions	Curriculum Development and Implementation Directorate (CDID), Mathematics and Science Improvement Center (MSIC) and other concerned directorates	[No change]
Target Groups	Grade 1-8 primary school students	Grade 1-8 primary school students Grade 1-8 mathematics teachers Grade 9-12 students Grade 9-12 mathematics teachers CDID, MSIC Mathematics Experts Regional Education Bureaus' Mathematics Experts	Direct Beneficiaries Grade 9-12 students in all regions: 6,993,656 students Grade 9-12 mathematics teachers in all regions: 14,640 teachers CDID, MSIC Mathematics Experts Regional Education Bureaus Mathematics Experts of all regions Indirect Beneficiaries Grade 1-8 students in all regions 24,620,963 students Grade 1-8 Mathematics teachers in all regions (46,244 teachers)
Super Goal	Quality of basic education is improved	The learning performance in mathematics is improved	[No change]
Overall Goal	Students' learning outcomes of satellite schools in model-school clusters are improved	Educational activities based on the new mathematics curriculum are promoted	[No change]
Project Purpose	A scale-up model for improving students' learning outcomes in mathematics is developed	Educational activities based on the new mathematics curriculum are introduced	[No change]
Outputs	Output 1: Reasons for lower academic achievement of primary school students in mathematics are analyzed Output 2: Lesson support materials for students and teachers are developed in	Output 1: Quality of the mathematics curriculum documents (flow charts, MLCs, and Syllabi) are assured Output 2: Technical recommendations, based on the situational analysis	Output 1: Quality of the mathematics curriculum documents (flow charts, MLCs, and Syllabi) is assured Output 2: Technical recommendations, based on the situational analysis

	grade1-8 mathematics Output 3: Good practices in implementing lesson support materials for students and teachers are identified in each model school Output 4: A scale-up model is evaluated in evaluation schools Output 5: Recommendations for revising curriculum and textbooks are compiled	of classroom practices, are incorporated to Grades 9-12 textbook editing strategies and M&E Output 3: The capacity in developing Grades 1-8 mathematics teaching materials are improved through technical WS Output 4: The quality of Grades 9-12 textbook contents are improved Output 5: Strategies for improving the utilization of Grades 9-12 textbooks are proposed based on monitoring and evaluation	of classroom practices, are incorporated to Grades 9-12 textbook editing strategies and M&E Output 3: The capacity in developing Grades 1-8 mathematics teaching materials are improved through technical WS Output 4: The quality of Grades 9-12 textbook contents is improved Output 5: Strategies for improving the utilization of Grades 9-12 textbooks are proposed based on monitoring and evaluation
Remarks	See Appendix 1	Completely revised from version 1	Based on version 3, objectively verifiable indicators are specified and some activities are modified. See Appendix 2

2.3 Final PDM Version 4

See Appendix 2 for the final version (version 4) of PDM.

3 PROJECT INPUTS

3.1 Work Flow

See Appendix 4 for Work Flow.

3.2 Work Plan

See Appendix 5 for Work Plan.

3.3 Assignment of Ethiopian Experts

Following 13 experts have been assigned as counterpart experts to work for MUST.

- CDID: 3
- MSIC: 7
- TELDD: 1
- NEAEA: 2

Table 3.1 shows their names and affiliations.

Table 3.1 Counterpart Experts

Name	Sex	Affiliation	Subject	Position
Zafu Abraha	F	CDID	Physics	Natural Sciences Education Curriculum Desk Head
Matebie Alemayehu*	M	CDID	Mathematics	(Career and Technical Education Curriculum Desk Head)
Tesfaye Sileshi*	M	CDID	Mathematics	Curriculum Expert
Tesfu Tezera	M	MSIC	Mathematics	Expert
Assefa Teferi	M	MSIC	Mathematics	Expert
Bimerew Kerie	M	MSIC	Mathematics	Expert
Daniel Demissie	M	MSIC	Mathematics	Expert
Getachew Debela	M	MSIC	Physics	Expert
Etenesh Mekonnen	F	MSIC	Biology	Expert
G/Egziabher Araya	M	MSIC	Chemistry	(Retired)
Yibeltal Solomon	M	TELDD	Mathematics	Expert
Abiy Kefyalew	M	NEAEA	Mathematics	Expert
Libeyin Teshome	M	NEAEA	Mathematics	Exam Development Expert

Note: * Mr. Matebie, formerly a curriculum expert, has been promoted to Career and Technical Education Curriculum Desk Head. Mr. Tesfaye has succeeded him as mathematics curriculum expert since September 2022.

Originally, when MSIC was the main counterpart agency, all those counterpart experts listed above were actively involved in the project activities. However, after the PDM was first revised and CDID became the main counterpart agency in December 2020, CDID did not accept the involvement of experts from other agencies on the ground that CDID should bear sole responsibility for curriculum and textbook reform in the Ministry of Education. Since MUST often required specific expertise of those experts outside CDID, the JICA Expert Team for MUST repeatedly asked CDID to have them participate in project activities but, unfortunately, no permission was granted. This, in the final stages of MUST, resulted in a shortage in resource persons who can disseminate the A-D-E-E concept developed by MUST throughout Ethiopia.

3.4 Assignment of Japanese Experts

Fourteen experts have been assigned to this project. During Period 2 (2 years), they spent a total of 55.20 person-months (41.80 in Ethiopia and 13.40 in Japan) carrying out their assignments. Table 3.2 below summarizes the experts and their respective person-months. See Appendix 6 for details.

Table 3.2 JICA Experts Assignment (Period 2)

Name	Title	Person-Months in Ethiopia	Person-Months in Japan	Total Person-Months
Norimichi Toyomane	Team Leader/ Mathematics Education	11.17	0.50	11.67
Nahoko Chiku	Deputy Team Leader/ Mathematics Education	8.33	0.85	9.18
Shimboku Miyakawa	Development of Mathematics Materials 1	1.97	0.93	2.90
Kan Motoyama	Development of Mathematics Materials 2	3.00	0.90	3.90
Etsutaro Tanaka	Development of Mathematics Materials 3	4.80	0.60	5.40
Kazumi Katsumata	Development of Mathematics Materials 4	4.23	3.15	7.38
Ken Furukawa	Development of Mathematics Materials 5	1.77	1.10	2.87
Yuta Yoneda	Development of Mathematics Materials 6	0.00	1.25	1.25
Izumi Nishitani	Mathematics Curriculum	0.00	0.80	0.80
Masaomi Hirose	Materials Editing	0.00	0.00	0.00
Michiru Yabuta	Monitoring 1/ Project Administration 1	0.90	1.20	2.10
Akira Sakayori	Monitoring 2/ Development of Mathematics Materials 7	2.03	0.35	2.38
Shunsuke Nishioka	Monitoring 3/ Project Administration 2	0.00	1.35	1.35
Masato Kamoda	Monitoring 4/ Project Administration 3	3.60	0.35	3.95
Total		**41.80**	**13.33**	**55.13**

Note: A long-term JICA Expert, Yumi Sekiguchi, has been assigned in Ethiopia since April 2021 and working to carry out part of the MUST activities according to the PDM.

3.5 Facilities and Equipment Provided

MoE has provided an office space for MUST throughout Period 2. It was first located in MSIC but later in October 2022 moved to CDID.

JICA has provided equipment listed in Table 3.3.

Table 3.3 Equipment Provided by JICA

Item	Location of Installation	Quantity
Vehicle	CDID	2
Copy Machine	Project Office (CDID)	1
Color Printer	Project Office (CDID)	2
Black and White Printer	Project Office (CDID)	1
Laptop Computer	Respective offices of the counterpart experts	10

4 PROJECT ACTIVITIES

4.1 Outputs, Activities and Achievements

As described in Section 1.6 above, MUST has been tasked to achieve five Outputs and carry out various Activities to produce the Outputs. Put in more concrete terms, MUST has basically pursued to assist CDID in assuring ***the quality of curriculum documents for G1-G12 and textbooks and teacher's guides for G9-G12*** in mathematics. After its four and a half years of operation, MUST has made three main achievements:

1) Successful introduction of "unitization" or, in other words, A-D-E-E structured textbooks and lessons (first of its kind in Ethiopia);[1]
2) Verification of the positive effect of the structured textbooks and lessons on students' better achievement in mathematics; and
3) Development of a set of resource materials to facilitate teachers to conduct A-D-E-E lessons using the new textbooks, and its nationwide introduction.

In this Chapter, how each Output has been achieved through various Activities will be described in some detail.

4.2 Activities Related to Output 1

4.2.1 Output 1

In the final version of PDM, Output 1 and Activities to achieve it are defined as follows:

Output 1: Quality of the mathematics curriculum documents (flowcharts, MLCs, and syllabi) is assured

Activities for Output 1:

1. Make a technical support plan
2. Conduct (online) technical support of the curriculum materials (flow charts, MLC, and syllabi) for Grades 1-12
3. Revise and finalize the curriculum materials
4. Conduct a validation workshop for the curriculum materials

Thus, activities to achieve Output 1 are mainly to improve the quality of the curriculum documents.

4.2.2 Technical Support for Curriculum Development

Even before the revised R/D was officially signed, CDID made a request to JICA Ethiopia Office in January 2021 to conduct an online workshop on curriculum development targeting the developers of the curriculum-related documents selected from the five universities. The purposes of the workshop were specified as: i) to develop the standards and tools for curriculum development; and ii) to develop the capacity of curriculum developers of all subjects.

Following this *ad hoc* request, the JICA Expert Team for MUST quickly prepared a workshop on curriculum development. The first day (January 20) was devoted to the general presentations on curriculum development (presented by Mr. Yoshitaka Tanaka from IDCJ) and the second day (January 22) focused on mathematics curriculum as an example (presented by Ms. Kazumi Katsumata, JICA Expert for MUST). At the end of the first day, CDID further requested to repeat the day 1 contents in the third day (January 23) to additional participants. The first and second days were attended by 17 CDID personnel (14 curriculum experts, Director General, Advisor, Acting Director) while the third day had about 50 attendants (about 20 curriculum development experts from MoE, 15 coordinators from the five universities, 15 CDID experts). According to the participants' remarks, the contents were well received and the participants' satisfaction was high.

[1] "Unitization" is a term coined by MUST. It means organizing textbook pages like standardized units, each of which contains, in principle, Activity, Definition, Example and Exercise (A-D-E-E). This one unit should be taught in one lesson.

4.2.3 Improving the Curriculum Documents

The curriculum documents (flowcharts, MLCs and syllabi) were developed by a team of mathematics experts convened from four universities. The Math Team (as it was called) was made up of the following members (Table 4.1).

Table 4.1 Math Team Members for Developing the Curriculum-Related Documents

	Name	Sex	Position	University
1	Asnakew Tagele	M	Math Team member	Bahir Dar University
2	Kidus Hunegnaw	M	Math Team member (Coordinator)	Bahir Dar University
3	Adem Mohammed*	M	Math Team member	Bahir Dar University
4	Tesfaye Tadesse	M	Math Team member	Hawassa University
5	Tadele Mekonnen*	M	Math Team member	Hawassa University
6	Chernet Tuge	M	Math Team member	Jimma University
7	Wesen Legesse*	M	Math Team member	Jimma University
8	Mulugeta Atnafu	M	Math Team member	Addis Ababa University
9	Abera Abate*	M	Math Team member	Addis Ababa University

* Also assigned later as Textbook Writer.

The Math Team developed draft documents during December 2020 and January 2021. The drafts were shared with the JICA Expert Team for MUST on March 1, 2021. The JICA Expert Team quickly reviewed the documents and submitted their main comments to CDID on March 8. Additional detailed comments, summarized by grade and by domain, were also submitted to CDID on March 11. Table 4.2 summarizes the eight main suggestions on syllabi provided by the JICA Expert Team:

Table 4.2 Eight Main Suggestions on Syllabi G1~G12

1.	Too many lesson periods allocated for one year
2.	Big Units should be divided into smaller Units
3.	Divide the Unit on “numbers up to 20” into three smaller Units (G1)
4.	Move multiplication from G1 to G2; move division from G1 to G3
5.	Move introduction of negative numbers from G5 to G7
6.	Improve the treatment of the graph of linear functions
7.	Reorganize geometry (G1 to G8)
8.	Reorganize measurement (G1 to G4)

On March 16-17, 2021, CDID organized a validation workshop inviting curriculum developers in all regions. On March 17, the JICA Expert Team had an opportunity to present how it worked to support the Math Team to draft and finalize the curriculum documents for mathematics. The Math Team subsequently finalized the three documents on March 18 and officially submitted them to CDID on March 19. The documents then became the official versions authorized by CDID.

4.2.4 Limitations

The whole activities related to Output 1were severely constrained by time. The time constraint worked to limit the quality of the curriculum documents in two ways.

Too little time to organize better syllabi

First, the Math Team itself could not have enough time to develop a better-organized system of syllabi from G1 to G12. Since the previous system of syllabi apparently had many inconsistencies and shortcomings, it was a golden opportunity for Ethiopia to critically review the whole syllabi and replace them with better-organized ones developed from scratch. Nonetheless, this opportunity was not fully utilized simply because the time given to the Math Team was too short. As a result, the Math Team was obliged to adopt a piecemeal approach, adjusting some parts and modifying other parts, but keeping the

basic framework almost intact. The most serious defect seems to be that the Math Team did not have time to thoroughly deliberate on what syllabi of mathematics best fit Ethiopia's needs on the one hand and reality on the other. This lack of philosophical and practical basis for the syllabi inevitably led to "all-inclusive" syllabi without a sharp sense of objectives and necessity. The all-inclusive syllabi are the main reason why revised textbooks are so voluminous, particularly at the secondary level.

Too little time to accept comments

The Math Team did not have enough time, either, to revise their drafts according to the comments they received (including those from the JICA Expert Team for MUST). Generally speaking, the eight main suggestions listed above were more or less accepted. However, other detailed comments, particularly those about higher grades from G9 to G12, were mostly left unattended even though the Math Team members seemed to understand the points and agree with them. It was presumably because they did not have enough time to revise them, exhausting time before reaching higher grades.

4.2.5 Achievement of Output 1

Activities were all carried out as specified in PDM. Overall level of achievement of Output 1, however, may be below 100%. Severe time constraint particularly on the curriculum developers (Math Team) prevented the thorough improvement of the curriculum documents, syllabi in particular. As will be pointed out in this report later, the new syllabi as a result contain many shortcomings unattended. Those shortcomings should be fully corrected in the next occasion when a new round of curriculum reform is to be initiated by MoE.

4.3 Activities Related to Output 2

4.3.1 Output 2

Output 2 and Activities to achieve it are defined as follows:

Output 2: Technical recommendations, based on the situational analysis of classroom practices, are incorporated to Grades 9-12 textbook editing strategies and M&E

Activities for Output 2:

1. Conduct a situational survey
2. Make concrete recommendations during the development process to improve Grades 9-12 textbook editing

4.3.2 Situational Survey and Findings

MUST conducted the G9-G12 situational survey on April 19-24, 2021, as a fully collaborative work between the Ethiopian counterpart team and the JICA Expert Team, as part of its activities for Output 2. In consideration of COVID-19 situation, it targeted only six secondary schools selected from Addis Ababa and no schools from other regions. They were: Ayar Tena (Rural), Dej Balcha (Urban), Kokebe Tsibah (Urban), Medhanealem (Rural), Misrak Goh (Urban) and Wondyirad (Rural). In the survey, the MUST Team conducted 1) achievement test for G9 ~ G12 students, 2) questionnaire and interview survey of math teachers, and 3) lesson observations of math lessons. Since this survey was implemented during the second trip ban, only one member of the JICA Expert Team could take part in its implementation.

Table 4.3 Outline of G9-G12 Situational Survey, April 2021

Dates:	April 19-24, 2021
Target Schools:	Six secondary schools in Addis Ababa (3 urban, 3 rural)
Participants:	About 1200 students, 60 math teachers
Survey Tools:	Achievement Tests (G9, G10, G11, G12) Teacher's questionnaire Lesson observation sheet
Surveyors:	2 experts from MoE, 6 experts/teachers from Addis Ababa Education Bureau, JICA Advisor, JICA Expert Team member and staff

Main findings from the survey were summarized as follows:[2]

1) Generally, students' performances are not satisfactory. It is evident that only few secondary school students have mastered the primary mathematics. Consequently, their understanding of secondary-level contents is low as well.

2) The current textbooks seem to be too difficult for most students. It may be necessary to adjust the difficulty level of the contents and exercises in the textbooks in line with the actual student achievement level identified in this survey.

3) On average, seven minutes were given to the students to solve exercises. However, much of the time was consumed to copy the blackboard first.

4) Students do not bring their textbooks to class because they are voluminous and heavy to carry and/or not used in the class.

5) One-third of the surveyed teachers are not provided with the Teacher's Guide from their schools.

6) More than one-third of the teachers cannot carry out the annual teaching plan as planned. They are obliged to omit some contents.

7) Students commonly receive homework and half or three-fourths of them duly do homework. Almost 90% of teachers check students' homework at the beginning of the following lesson. This particular practice, however, may affect time management of the lesson.

8) To improve students' understanding, several teachers emphasized the importance of reducing the number of contents, as well as aligning the difficulty level of the textbook to students' actual competency level.

Based on those findings, following recommendations were formed about the development policy for the new textbooks and teacher's guides:

Textbooks

1) Make them thinner with strictly selected contents.

2) Structure the pages so that one or two pages can be taught in one lesson.

3) Design the standard lesson flow and page format: Problem→Solution→Conclusion→Exercise or Key concept→Problem→Solution→Exercise.

4) Always give concise explanations to key concepts or key formulae.

5) Select exercise problems. Avoid excessively difficult items. Give easy and simple exercises first for students to be able to solve for themselves.

6) Provide a few question items for teachers to use for assessment purposes.

Teacher's Guides

1) Reduce the volume by strictly selecting the contents.

2) Organize the contents with clearer sequence.

3) Expand the section on "Introduction of unit and unit outcomes" by explaining pre-requisite knowledge to learn the topic and providing a review section.

4) Also expand the section of "Active learning and continuous assessment required" by, for instance, providing some standard question items to be used to assess the students' understanding about the topics.

4.3.3 Five Viewpoints (Directions) as Editing Strategy

Though the new syllabi were authorized in March 2021, the Textbook Developers were late to be officially

[2] The results are documented in *Report on the G9-G12 Mathematics Survey* submitted in May 2021.

assigned. The 18 Textbook Developers were finally appointed by the Center of Excellence by July 2021.[3] MUST then held an online workshop on July 12, 2021, inviting the Textbook Developers to Bishoftu. One of the main objectives of this workshop was for the Textbook Developers to deliberate and agree on their editing policy of the textbooks. To facilitate their discussion, the JICA Expert Team made presentations about the Team's recommendations on the editing policy, formed from the findings of the situational survey and other previous analyses. The Textbook Developers, however, could not come up with a unified editing policy in the workshop due mainly to insufficient time. Thus, they had to start drafting the textbooks without clear-set policy. They submitted the first drafts to CDID after two months in September 2021.

The first drafts (called "draft zero") were quickly forwarded to the JICA Expert Team for MUST. The JICA Expert Team reviewed them and found numerous points to be revised. Apart from various inconsistencies, their most serious shortcoming seemed to be that they adopted the same format as the previous textbooks. Consequently, draft zero lacked clear lesson-wise structure and was full of too difficult examples and exercises to be given to the first learners. The JICA Expert Team's overall judgment, unfortunately, was that draft zero's general quality was lower than that of the previous textbooks.

It seemed highly necessary to take a strategic approach to improve draft zero. Since there were so many major and minor points to be revised, the JICA Expert Team for MUST proposed to categorize them into five types (viewpoints) [from easy/simple to difficult/complicated] and revise the draft stepwise, focusing on one type (viewpoint) of revisions at one time. Thus, the JICA Expert Team proposed the following five viewpoints to be tackled stepwise:

Table 4.4 Five Viewpoints (Directions) for Draft Improvement

1)	Correction of mistakes
2)	Improvement in layout, mathematical expressions, terms, graphs, figures, etc.
3)	Improvement of the structure of Activity-Definition-Example-Exercise (A-D-E-E) by adopting the essence of the standard lesson flow (particularly applying the "1 topic, 1-2 pages" principle)[4]
4)	Modification of problems at the right level of students' learning
5)	Improvement/enrichment of the contents

At the same time, the JICA Expert Team proposed to revise the draft textbooks gradually in two stages:

Stage 1 [September and October 2021] Focusing on Viewpoints 1, 2 and 3 (partly)

Stage 2 [November 2021~May 2022] Focusing on Viewpoints 3 (partly), 4 and 5

Those points were proposed to CDID and agreed upon on September 29, 2021.[5]

Thus, the five viewpoints above came to practically guide the whole revisional work by the Textbook Developers and the JICA Expert Team in the following stages. For more details, see Section 4.5 Activities Related to Output 4 below.

4.3.4 Achievement of Output 2

The situational survey conducted in April 2021 produced a number of useful insights and suggestions to the improvement of the teaching and learning materials under MoE's revision. The findings have effectively guided MUST in the following course of activities and, therefore, the overall level of

[3] For details and a list of Textbook Developers, see Section 4.5.2.

[4] The JICA Expert Team originally recommended Problem→Solution→Conclusion→Exercise (P-S-C-E) structure. In consideration of a basic requirement ("Activity is a must") commonly imposed on the Textbook Writers, however, it later modified the recommended structure to Activity→Definition→Example→Exercise (A-D-E-E).

[5] Meeting Memorandum, signed on October 11, 2021.

achievement of Output 2 is satisfactory.

4.4 Activities Related to Output 3

4.4.1 Output 3

Output 3 and Activities to achieve it are defined as follows:

***Output 3*:** The capacity in developing Grades 1-8 mathematics teaching materials are improved through technical WS

Activities for Output 3:

1. Create a technical support plan for REB textbook writers
2. Develop Grades 1, 4, 7 teaching and learning material samples for the main purpose of capacity development for Grades 1-8 REB textbook writers
3. Conduct workshops for REB textbook writers to develop the capacity to write textbooks

4.4.2 Sample Textbooks and Teacher's Guides for Grades 1, 4, 7

As is seen in the original PDM (Appendix 1), MUST initially aimed at producing "lesson support materials on mathematics for students and teachers in Grades1-8" (Output 2). To achieve this, the JICA Expert Team for MUST in 2019 started developing Lesson Support Materials for Grades 1, 4 and 7, the three primary grades designated to be piloted in the first stage beginning in September 2020.[6]

This whole plan, however, came to a complete stall in 2020 due to multiple untimely events and, consequently, a thorough revision of PDM became inevitable. A revised PDM was finally agreed on and signed on February 26, 2021. In the new PDM, MUST's main output is no longer the Lesson Support Materials for Grades 1-8 but quality assurance of teaching and learning materials for Grades 9-12. Accordingly, the Lesson Support Materials for Grades 1, 4 and 7 being almost completed by then changed their status from MUST's main output to the samples to be provided to REBs, newly responsible for developing the primary textbooks and teacher's guides under the renewed MoE policy (see Section 2.1 above for details).

The JICA Expert Team for MUST continued its development of the Lesson Support Materials for Grades 1, 4 and 7 until July 2021, the end of Period 1. The completed textbooks and teacher's guides were submitted to CDID and JICA as the references for regional G1-G8 textbook development and as the main output prescribed in the initial PDM.

4.4.3 Technical Workshop for Regional Textbook Developers

On request by CDID, the JICA Expert Team conducted a technical workshop on April 26-28, 2021, for G1-G8 textbook developers in regions. It was aimed to familiarize them with the whole process of textbook development and how the editing policy should be established. A total of 33 curriculum experts attended the workshop, coming from 10 REBs (Table 4.5). The main venue was in Adama but some Japanese participated from Addis Ababa online and most members of the JICA Expert Team also took part online from Japan as well.

Acting Director of CDID first presented about the framework of the curriculum reform and the revised curriculum. Mr. Matebie, then Mathematics Expert from CDID, explained the overall process of textbook and teacher's guide development. The JICA Expert Team then made successive presentations on the current status of mathematics education of Ethiopia, and experiences of textbook development taken from a few other countries and MUST. The participants further worked in groups to deliberate on the editing policy appropriate for their own regions and to develop sample pages of textbooks based on the editing policy. After their presentations on the last day, the JICA Expert Team gave concrete and practical comments on their policy and sample pages.

It was originally intended to distribute the draft Lesson Support Materials for Grades 1, 4 and 7 as samples to the participants of this workshop but this plan was cancelled at the last moment because CDID did not

6 See Section 2.1 above.

approve it.

Table 4.5 Participants of the Technical Workshop for G1-G8 Textbook Developers in Regions

No	Region/City	Name	Sex	Designation
1	Addis Ababa	Getachew Talema	M	Curriculum director (Amharic)
2		Robi Wabi	M	Curriculum director (Oromic)
3		Fekadu Fantaye	M	Mathematics curriculum expert
4		Teshome Degefu	M	Textbook development unit expert
5		Muluneh T/birhan	M	Physics curriculum expert
6		Solomon Wendimu	M	Textbook development unit expert
7		Kebede Degefa	M	Textbook development unit expert
8	Afar	Hajji Bulo	M	Curriculum director
9		Girma Kifle	M	Mathematics curriculum expert
10		Dawit Michael	M	Textbook development unit expert
11	Benishangul Gumuz	Habte Eariso	M	Mathematics curriculum expert
12		Temesgen Wedi	M	Textbook development unit expert
13	Dire Dawa	Girma Mekonnen	M	Mathematics curriculum expert
14		Anteneh Abebe	M	Textbook development unit expert
15	Gambela	Alamrew Alene	M	Curriculum director
16		Etsey Gidey	M	Mathematics curriculum expert
17		Tesfaye Tadesse	M	Textbook development unit expert
18	Harari	Yewendosen Girma	M	Curriculum director
19		Daniel Birhane	M	Mathematics curriculum expert
20		Dawit Legesse	M	Textbook development unit expert
21	Oromia	Dereje Tadesse	M	Curriculum director
22		Weyitu Bekele	F	Mathematics curriculum expert
23		Taye Mamo	M	Textbook development unit expert
24		Gebremichael Abemsa	M	Curriculum Dept. Group Leader
25		Tilahun Alemu	M	Mathematics expert
26	Sidama	Abebe Zedagim	M	Mathematics curriculum expert
27		Daniel Tona	M	Textbook development unit expert
28	SNNPR	Endashaw Yismaw	M	Curriculum director
29		Natan Labiso	M	Mathematics curriculum expert
30		Sahilu Tsige	M	Textbook development unit expert
31	Tigray	Aster Yitbarek	F	Curriculum director
32		G/Meskel G/Egziabher	M	Mathematics curriculum expert
33		Silas Araya	F	Textbook development unit expert

Note: No participants attended from Amhara and Somali Regions.

4.4.4 Evaluation of the Workshop

This Technical Workshop for Regional Textbook Developers was held under three unusual constraints. First was that it was organized in a very hasty manner because of CDID's sudden decision and request. There was no sufficient time for the JICA Expert Team for MUST to prepare everything including questionnaire survey. Second constraint was that no JICA experts were present at the main venue in Adama due to the trip ban after COVID-19. Some managed to participate online from Addis Ababa but most others had to join the workshop online from Japan. Third constraint was that this workshop has turned out to be the only opportunity for the JICA Expert Team for MUST to collaborate with regional textbook developers and stakeholders. Initially, JICA experts intended to evaluate the impact of this technical workshop by reviewing the textbooks developed by respective regions but this plan later proved impossible because CDID prohibited the JICA Expert Team to contact REBs directly or obtain draft textbooks for review in fear of constitutional violation. Consequently, the JICA Expert Team for MUST was left with no way to evaluate the impact of the workshop.

In 2022, the JICA Expert Team nonetheless tried to conduct a questionnaire survey with REBs after CDID's kind permission and facilitation. This initiative, however, was turned down by REBs, who doubted if the only one workshop ever had any effect on the textbook developers' capacity building.

Given this reaction by REBs, the JICA Expert Team changed its approach to the evaluation. It decided to contact the individual participants directly over the phone and ask a few selected questions only. Telephone interviews thus modified were successfully conducted in November and December 2022.

Interviewees

Out of the 33 regional participants, ten agreed to respond to the questions when contacted. However, two of them were not directly involved in textbook development and excluded from the evaluation. The roles of the eight interviewees were as follows:

- Evaluator: 4
- Coordinator: 2
- Evaluator and Coordinator: 1
- Quality Assurance Officer: 1

Even though the total number of interviewees was small compared to the total number of participants, the responses given by them were serious and conscientious as will be shown below. We can take them as reliable and representative samples of the whole participants.

Procedure of the Interview

The structured interviews were conducted during November-December 2022, one year and eight months after the workshop. The interview script was prepared in English by Japanese experts, and Ethiopian research assistant conducted the interviews in Amharic. The questions asked in the interview were listed in Table 4.6:

Table 4.6 Questions Asked in the Interview

1.	What is your name?
2.	Which region are you working for?
3.	Which grade of math textbook development were you in charge of?
4.	Which role of textbook development were you in charge of? *e.g.*) writer, editor, evaluator, illustrator, designer
5.	Was the situation analysis useful for your work of textbook development? (If YES, ask how s/he utilized the experience. If NO, ask why s/he thinks so).
6.	Was the discussion or activity on editing policy useful for your work of textbook development? (If YES, ask how s/he utilizes the experience. If NO, ask why s/he thinks so.)
7.	Were these activities, making a learning unit plan and sample textbook page, useful for your work of textbook development? (If YES, ask how s/he utilizes the experience. If NO, ask why s/he thinks so.)
8.	Lastly, which topic(s) you learned during this workshop was most useful for your work. Please explain why you think so.

Analytical Results 1: What They Learned

JICA experts categorized the interview statement by coding. The codes and some examples of the statements are shown in Table 4. 7. Table 4.8 shows the count of the codes.

Table 4.7 Codes for the Analysis of the Interviews

Code	Examples of the Statement in Interview
difficulty	"It helped us to develop textbooks that are to the level of students" "Some contents in the previous textbooks were above the level of the learners. It helped me to check if the new manuscripts were to the level of the learners"

volume	"Our textbooks were big and both students and teachers did not like to carry them to schools" "Editing policy helped me to decide the volume"
application	"They adopted the ADEE structure which is important to decide the contents appropriate for one period" "He used editing policy to apply the knowledge and skills he got in the textbook development"
teacher	"Unit plan was the most useful content because activities of the teacher would be based on the unit plan and this would help the teacher to exactly know what he would do in that specific period" "We added some useful lesson plans that may serve as a model for teachers"
modern education	"It helped me in setting questions that stimulate critical thinking" "It also helped me understand that our curriculum did not consider the knowledge and skills required for the twenty-first century"
annual plan	"It used to be difficult to finish the textbooks in one academic year. Now the textbooks are divided into periods available in the academic year and there cannot be any reason not to finish the textbook. Every topic has allotted period(s)"
one topic	"It was very useful and it helped me to make a lesson be based on a single objective" "In the previous textbooks, there could be more than one competency in one topic. It will help them to develop a lesson with one competency and make it easier to learn"
unexpected	"They even shared it with their CTE to consider it in pre-service training"

Table 4.8 Counts of the Codes by Workshop Sessions

Session	difficulty	volume	application	teacher	modern education	annual plan	one topic	unexpected
Overall	15	7	6	5	3	2	2	1
Situation Analysis	7	2	--	1	--	--	--	--
Editing Policy	3	4	3	--	3	--	--	--
Unit Plan	1	--	2	2	--	2	2	--
Most Useful Session	4	3	1	2	--	--	--	1

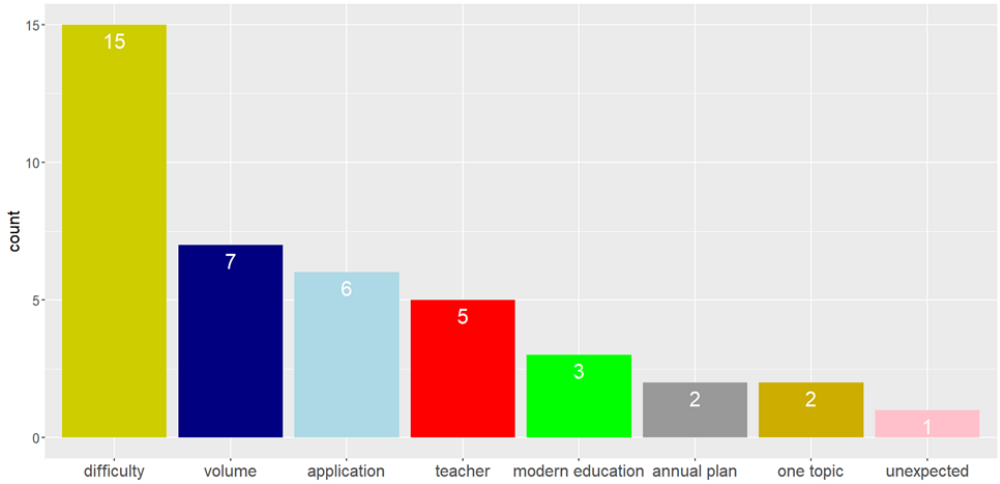


Figure 4.1 Counts of the Codes: Overall

Throughout the interviews, the statements coded "difficulty" were made most often. The code second often mentioned was "volume," but there was a large difference between their counts. It suggests that the workshop made the participants most clearly realize that the current textbooks were too difficult for

students.

Regarding the Situation Analysis session, many interviewees referred to “difficulty.” In this session, the results of MUST baseline survey were shown to the participants. The data of low achievement drove the participants to understand the real level of the students’ achievement and the necessity of developing textbooks suitable for the level of the students.

During the Editing Policy session of the workshop, the participants tried to make their own policy for developing textbooks and teaching guides. This mock experience nonetheless urged them to think over one serious problem with the current textbooks: bulkiness. In the interviews, four interviewees mentioned “volume” in the context of reducing the bulkiness of textbooks, reflecting the situation where students do not bring them to school. Many of the interviewees also mentioned “application” in their statements, which indicates their ability and willingness to directly apply the knowledge and skills they learned in the Editing Policy session.

The participants also made unit plans and a sample page of the textbook in the Unit Plan session. The interviewees mentioned “annual plan,” “one topic,” and “teacher,” which were well related to the actual work of teachers. A comment about the “annual plan” was that the current curriculum made it difficult to finish the textbook in one year and that creating a unit plan would solve this problem. Regarding the "one topic," the interviewees well understood that limiting the number of competencies to be covered in one lesson would make it easier to design the lesson and make it easier for the students to learn. A comment about “teachers” was that a unit plan facilitates teachers to know what to teach their students.

There were no notable characteristics in the responses about the session that was most useful (see Figure 4.2). An interviewee said, “All are interconnected, and difficult to see them separately, all are important.”

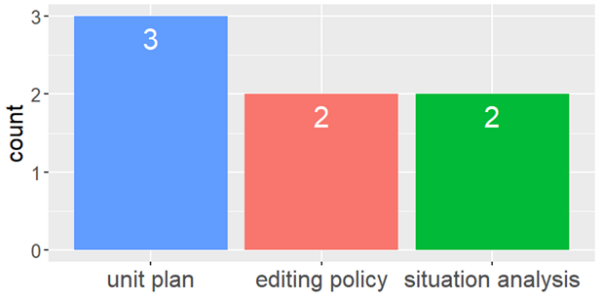


Figure 4.2 Counts of the Most Useful Session

Eight interviewees all answered that the contents of the workshop were beneficial for their textbook development. Thus, by applying this percentage to the whole group, we can safely conclude that Output 3 was achieved with respect to the Objectively Verifiable Indicator: 60% of participants of the technical WS have learned new knowledge for textbook development to apply in developing Grades 1-8 mathematics textbooks.

Analytical Results 2: How They Utilized What They Learned

Analytical Results 1 focused on “what” the participants leant in the workshop. Next, we analyze “how” the participants utilized the knowledge they gained in the workshop in textbook development. The purpose is to judge whether MUST achieved the Objectively Verifiable Indicator 3 of the project purposes: 60% of participants of the technical WS have applied the knowledge learned during the WS in order to produce Grades 1-8 textbooks. Table 4.9 shows the codes and some examples of the statements related to concrete action.

Table 4.9 Concrete Action for Textbook Development

Code	Examples of Statements Related to Concrete Action for Textbook Development
difficulty	- write considering their condition - focus on the basic contents - present contents in simpler ways for student

volume	- reduce the huge content and volume of their textbooks - decide volume
application	- used editing policy - adopted ADEE structure
teacher	- added some useful lesson plans
modern education	- setting questions that stimulate critical thinking
annual plan	- the textbooks are divided into periods available in the academic year - allot periods available to lessons
one topic	- make a lesson be based on a single objective - develop a lesson with one competency
unexpected	- shared it with CTE to consider it in pre-service training

The analysis suggested that all interviewees took some action on the knowledge they gained in the workshop. Hence, objectively verifiable indicator 3 was achieved. Figure 4.3 shows the counts of action under each code.

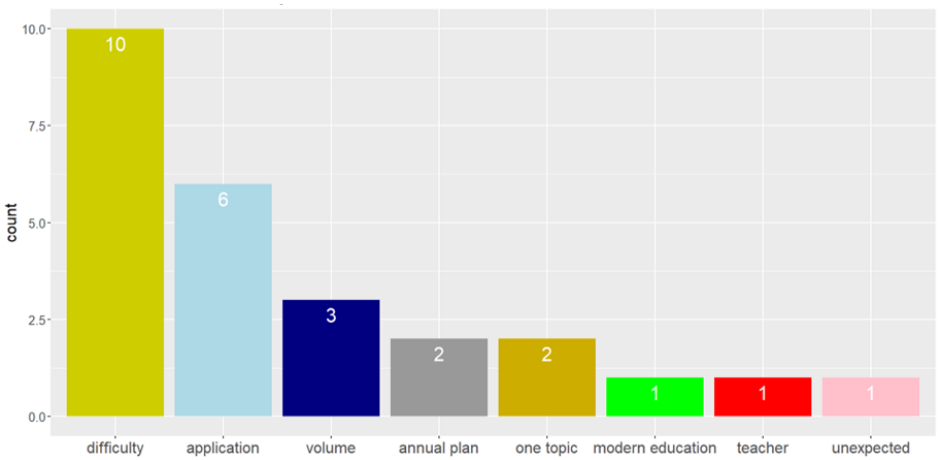


Figure 4.3 Counts of Action for Textbook Development

Just as “difficulty” was the most frequent statement in Analysis 1, “difficulty” was again the code most frequently cited in the action for textbook development. This implies that in the workshop the participants became acutely aware of the difficulty of the current textbooks, and as a result, took some action to rectify the problem.

In Analysis 1, the code second most frequently mentioned was "volume," but in this analysis, the second was "application." This may suggest that it was relatively easy to apply editing policy, A-D-E-E structure, or unitization to textbook development, but it was difficult to devise concrete ways to reduce the volume of the textbooks.

The workshop was the only opportunity for MUST to provide inputs to the textbook development by regions. Nonetheless, the interviews revealed that the workshop opened the eyes of the participants to the difficulty gap existing between the current textbooks and students’ actual achievement and that they kept this awareness vividly in their memory for more than one year. Subsequently, they even utilized the knowledge they gained in the workshop to develop their new textbooks.

4.4.5 Limitations

Though participants generally gave positive evaluation to the workshop, its effectiveness was limited in actuality. It turned out that very few of the participants took a role of textbook developer (writer, in particular) for themselves. All REBs opted to commission the development work to local outside resources such as university lecturers, CTE lecturers, and secondary school teachers whereas the workshop participants mostly took responsibility for their coordination and oversight. The JICA Expert Team could not invite those regional textbook developers to the workshop because at that time none of them had been appointed by respective REBs. Since CDID later prohibited the JICA Expert Team to contact REBs in

fear of constitutional violation, the technical workshop described above turned out to be the first and last opportunity for the JICA Expert Team for MUST to collaborate with REBs except Addis Ababa Education Bureau.

4.4.6 Achievement of Output 3

As it turned out, this Output 3 had to face strict constraints. The Lesson Support Materials for Grades 1, 4 and 7 were developed but not distributed to the Regions due to CDID's new policy. The technical workshop for G1-G8 Textbook Developers in Regions was held only once and no follow-up activities were possible. Even though some participants of the workshop indicated their high appreciation of and satisfaction with the workshop contents, MUST could not provide further support to them or other participants. Consequently, while all activities were carried out as specified, the overall level of achievement of this Output 3 should be evaluated less than 100%. If technical support to Regions is to be considered, it would require a project framework different from that of MUST.

4.5 Activities Related to Output 4

4.5.1 Output 4

Output 4 and Activities to achieve it are defined as follows:

***Output 4*:** The quality of Grades 9-12 textbook contents is improved

Activities for Output 4:

1. Conduct workshops for textbook developers to improve draft Grades 9-12 textbooks and teachers guide
2. Provide further technical support to improve draft Grades 9-12 textbooks and teachers guide

4.5.2 Workshops with Textbook Developers

In the revised PDM, this Output 4 constitutes the main pillar among the five outputs. Conducting Workshops with Textbook Developers is defined as the primary activity to attain Output 4.

The 18 Textbook Developers were finally appointed by the Center of Excellence around July 2021.[7] Table 4.10 below is a list of them.

Table 4.10 Textbook Developers for G9-G12 Mathematics

	Name	Sex	Role	Grade	University
1	Gurju Agiwchew	M	Writer	G9	Bahir Dar University
2	Adem Mohammed*	M	Writer	G9	Bahir Dar University
3	Tadele Mekonnen*	M	Writer	G10	Hawassa University
4	Mamo Teketel	M	Writer	G10	Hawassa University
5	Mohammed Yiha	M	Content Editor	G9-10	Hawassa University
6	Akalu Chaka	M	Curriculum Editor	G9-10	Hawassa University
7	Endalfer Melese	M	Language Editor	G9-10	Jimma University
8	Bahiru Chanie	M	Illustrator	G9-10	Hawassa University
9	Aknaw H/Mariam	M	Designer	G9-10	Jimma University
10	Tilahun Abebaw	M	Writer	G11	Addis Ababa University
11	Abera Abate*	M	Writer	G11	Addis Ababa University
12	Habtamu Garoma	M	Writer	G12	Jimma University
13	Wesen Legesse*	M	Writer	G12	Jimma University
14	Zewdu Desalegn	M	Content Editor	G11-12	Hawassa University
15	Solomon Melesse	M	Curriculum Editor	G11-12	Bahir Dar University
16	Melaku Wakuma	M	Language Editor	G11-12	Addis Ababa University

[7] The Center of Excellence is a consortium of five universities, which was commissioned by MoE to produce the new textbooks and teacher's guides of all subjects for Grades 9 to 12. The five universities are: Bahir Dar University, Hawassa University, Addis Ababa University, Mekele University and Jimma University. The Center of Excellence then recruited and appointed qualified professionals from among the teaching staff of the five member universities.

17	Zerihun Kinfe	M	Illustrator	G11-12	Hawassa University
18	Berie Getie	M	Designer	G11-12	Bahir Dar University

* Members of the Math Team that developed the curriculum documents.

When the Textbook Developers were appointed around July 2021, their overall work schedule indicated by CDID was roughly as follows:

July 2021	Commencement of work
September 2021	**Submission of the first draft ("draft zero")**
May 2022	Validation Workshop for Grades 9 and 10
September 2022	Piloting starts for Grades 9 and 10
November 2022	Validation Workshop for Grades 11 and 12
January~February 2023	Validation Workshop for Grades 9 and 10 after monitoring
May 2023	**Printing of the final versions starts**
September 2023	Full implementation of all grades starts

Thus, between September 2021 and May 2023, MUST can have about one and a half years of time to improve the draft textbooks and teacher's guides following the five viewpoints (directions) explained above (Table 4.4) and reproduced here:

1)	Correction of mistakes
2)	Improvement in layout, mathematical expressions, terms, graphs, figures, etc.
3)	Improvement of the structure of Activity-Definition-Example-Exercise (A-D-E-E) by adopting the essence of the standard lesson flow (particularly applying the "1 topic, 1-2 pages" principle)
4)	Modification of problems at the right level of students' learning
5)	Improvement/enrichment of the contents

Given this schedule, the JICA Expert Team for MUST proposed to CDID to conduct eight face-to-face workshops with the Textbook Developers for the purpose of gradually revising the drafts stepwise. CDID agreed with the proposal and promised to make necessary arrangements with the Center of Excellence to make the Textbook Developers able to attend the workshops. A plan of eight workshops was thus prepared.

In total, seven workshops were held during the period (one was cancelled due to a change in the schedule) more or less according to the original plan. Table 4.11 below summarizes the workshops with the Textbook Developers as conducted.

Table 4.11 Workshops with the Textbook Developers

SN	Dates	Venue	No. of Partici-pants	Main Agenda	Remarks
1	Oct 16~18, 2021	Adama Executive Hotel	18	- To explain the comments given by MUST and revise the draft accordingly - To practice "unitization" - To understand the revision tasks ahead after October 2021	
2	Feb 25~27, 2022	Ras Amba Hotel, Addis Ababa	14	- To work on the revision task of "unitization" and "modification of problems"	Delayed by about 2 months due to security situation
3	May 6~8, 2022	Ras Amba Hotel, Addis Ababa	7 (G11 and G12	- To work on the revision tasks of "unitization" and "modification of problems"	G9 and G10 were not invited in consideration

			only)	- To incorporate comments from Evaluators and MUST	of their recent Workshop held by Hawassa University on April 11~16 and CDID Validation Workshop on May 20~22
4	(G11 and G12) June 17~19, 2022 (G9 and G10) June 24~26, 2022	Ras Amba Hotel, Addis Ababa	9 (G11 and G12) 9 (G9 and G10)	(G11 and G12) - To work on remaining revision tasks of "unitization" - To identify the topic for each lesson (G9 and G10) - To work on remaining revision tasks of "unitization" - To identify the topic and evaluation questions for each lesson. If necessary, modify the evaluation questions - To prepare the unit plan based on No.2 - To work on the revision according to the Syllabus revision	
5	Aug 26~28, 2022	Rift Valley Hotel, Adama	18	- To revise the latest version of the textbooks further based on the comments given by MUST, particularly focusing on inter-grade consistency - To confirm Unit Plans - To revise the teacher's guides according to the revised version of the textbooks	
6	Nov 3~5, 2022	Ras Amba Hotel, Addis Ababa Kokebe Tsibah Secondary School	18	- To observe mathematics lessons using the piloted G9 and G10 textbooks and gain hints for further improvement - To revise the latest version of the textbooks further based on the lesson observations, comments given by teachers, MUST and other Textbook Developers - To review the teacher's guides according to the revised version of the textbooks and confirm the contents	
7	Dec 30, 2022 ~Jan 1, 2023	Ras Amba Hotel, Addis Ababa	18	- To make corrections in the latest version of the textbooks based on the comments given by MUST - To revise the teacher's guides according to the final version of the textbooks and the comments given by MUST	Lesson observation at a secondary school was cancelled due to time limitation
8	(mid-Feb 2023)				Cancelled due to the advancement of the final version deadline to Jan 2023

For a sample of the resultant new textbook, see Appendix 8 ("Quadratic Equations" from G9 Unit 3). For a comparison, see Appendix 7, taken from the current textbook on the same topic ("Quadratic Equations" from G9 Unit 2).

4.5.3 Evaluation of the Workshops

The Textbook Developers, recruited from the teaching staff of four universities throughout Ethiopia, were mostly appointed by the Center of Excellence while a few of them applied for the position. This assignment therefore meant an extra task to them (though to a different extent) apart from their daily teaching assignment. When they began to work for this job in July 2021, they did not have clear editing policy or writing instructions, or sufficient time to work (tasked to produce the first draft in two months by September 2021) or, as a team, any prior experience to work together for the same goal.

The July-12 online workshop organized by MUST was the first opportunity for them to meet. Though they could not agree upon any editing policy during the workshop, they nonetheless started their team work there. The following workshop held in October 2021 (the first face-to-face workshop with them) to discuss their draft zero turned out to be quite "different" to them. The JICA Expert Team for the first time introduced the totally new concept of "unitization" to them but, since it was so revolutionary to them, they generally remained skeptical about it.

Their attitude drastically changed in the second workshop held in February 2022. Since their deadline for the final version was approaching in May 2022, the JICA Expert Team decided to give them concrete sample pages of a few "unitized" lessons.[8] Supplemented by JICA experts' untiring explanations, this action proved highly effective to convince the Textbook Developers of the utility of the "unitization." They quickly grasped the essence of "unitization" and reorganized their draft Units into "unitized" ones. In this second workshop, they as a team understood and accepted "unitization" as the main mast of their "editing policy" to be followed collectively.

As the workshop continued, the Textbook Developers' understanding of the "unitization" concept deepened. They started to positively accept the numerous and meticulous comments given by the JICA Expert Team and, above all, dutifully attend the workshops that were held over the weekends. At the same time, subsequent workshops came to prove highly successful in their achievement.

Responses to a small questionnaire given to the Textbook Developers at the end of the 7th workshop show interesting remarks by them. Though respondents were not many (only eight out of 18), they almost unanimously evaluated their experience as Textbook Developer "very positively." To the following question of "Which experience do you value most positively?" they answered as follows:

- Lesson structure and Unitization
- Working with the JICA MUST team
- The teamwork
- Unitization
- I experienced team work and work in schedule
- The group discussion that we have with MUST
- accepting comments and incorporating into the material
- Lesson based textbook organization is what inspired me differently!

As is seen, three of them mentioned "unitization" as the most valuable experience and two mentioned "teamwork." This result, though small, indicates that the Textbook Developers accepted the novel concept of "unitization" and were satisfied with the successful experience of teamwork to accomplish the difficult task in time.

Their acceptance of "unitization" was not shallow. This is clearly indicated by some responses to the question, "Do you have anything to say to math teachers after this whole experience?":

- Solving difficult problems can't mean teaching but giving simple example and make them to know the basic things has much value on the performance of students.
- I recommend them the experience that we have before was not correct. Rather than giving a hard question it will be better to make the students to practice with very simple questions which

[8] In the early stages of MUST, providing samples to the Textbook Developers was strictly prohibited by CDID as an excessive interference in their independent work.

direct them to hard problems.

- I am sure that this textbook is much better than the previous textbooks and I kindly ask teachers to properly implement the teaching strategies suggested in the students textbook and teachers guide.
- Classroom teachers should show a good shift from a teacher-directed instruction to student-directed kind of instruction while conducting lessons.

Those comments all refer to the need of giving simple, basic examples to the students and providing exercise questions very similar to the examples. This is exactly the new teaching strategy lying beneath the "unitization" concept and what the JICA Expert Team repeatedly emphasized in the workshops. Their responses above testify that the Textbook Developers have deeply understood and accepted the benefits of "unitized" textbooks to improve students' achievement in mathematics.

To the last question of "If another opportunity is given, do you want to do the same thing again?" seven out of eight respondents answered positively saying:

- I have enough experience.
- I enjoyed the whole process and I want to be part of the improvement process.
- I got a lot of experience from the current assignment. It will be also good to serve the community in area.
- To learn more and to contribute more.
- I got a lot of experience in this project I want to apply that skill in future.
- I want to contribute to the community.
- Now, I have the experience.

Their highly positive attitude is impressive and shows no sense of regret. The only participant who answered No to the question was by no means negative. He said No because he thought he was not eligible to that task yet. He clarified the reason why:

- Textbook writing is a highly dynamic task. So, I may amend some of the parts of the textbook on the bases of the best experiences I will have by the time.

Thus, the Textbook Developers by and large value their whole experiences positively as Textbook Developer. The seven workshops with the Textbook Developers can therefore be evaluated successful in achieving its objectives in two ways: first, by producing better quality of mathematics textbooks and teacher's guides and, second, by causing profound changes in the Textbook Developers' perceptions.

CDID also highly evaluated the seven workshops with the Textbook Developers as an effective approach to improve the quality of the textbooks and teacher's guides. The step-by-step method adopted by the JICA Expert Team for MUST to improve the draft materials (see the five viewpoints explained above) and painstakingly repeating the process of drafting->commenting->revising->commenting->revising . . . were certainly effective in the given context. These whole experiences can be referred to again when CDID is to undertake the next round of curriculum reform some time later.

4.5.4 Achievement of Output 4

Output 4 has been fully achieved through the seven workshops conducted with the Textbook Developers. The quality of the final version of new textbooks and teacher's guides is far better than their first drafts (draft zero) and better than the current textbooks and teacher's guides as attested by the results of multiple tests administered on the students from pilot and non-pilot schools.

4.6 Activities Related to Output 5

4.6.1 Output 5

Output 5 and Activities to achieve it are defined as follows:

***Output 5*:** Strategies for improving the utilization of Grades 9-12 textbooks are proposed based on

monitoring and evaluation

Activities for Output 5:

1. Select MUST pilot schools and MUST non-pilot schools to verify the learning improvement mechanism
2. Conduct induction training to MoE pilot schools in CDID/MoE-organized workshops
3. Conduct pre-pilot training for Grades 9-10 math teachers at MUST pilot schools
4. Provide special support to Grades 9-10 math model teachers at MUST pilot schools
5. Conduct achievement tests and unit tests at MUST pilot schools and non-pilot schools
6. Conduct lesson observation at MUST pilot schools and non-pilot schools
7. Compile the results of MUST M&E activities
8. Conduct a nation-wide workshop to share the MUST/MoE pilot experiences among stakeholders
9. Collect data on Grades 9-12 textbook usage at the classroom level through M&E
10. Make strategies to improve the learning achievement of students using Grades 9-12 textbooks at the classroom level

All the activities listed above have been duly implemented in this period. Respective activities will be described in detail here below. Since many and a variety of Activities are listed under this Output, their descriptions will be far-flung and get lengthy.

4.6.2 Induction Training by Ministry of Education

Induction training in the form of Training of Trainers (ToT) was held twice by MoE targeting regional trainers who would cascade the same contents down to the school stakeholders. First was held for five days, from August 25 to 29, 2022, in Debra Birhan, Amhara, attended by eight REBs. Second followed for four days from September 4 to 7, 2022, in Bishoftu, Oromia, attended by the remaining four REBs. In the first training, three days were spent for subject-based presentation and discussion on three curriculum documents (content flow chart, syllabus, MLC), the draft TLMs (textbooks and teacher's guides), and weekly and daily lesson plans. Due to JICA's travel restriction effective at that time, the JICA Experts for MUST could not attend either training. On their behalf, the CDID mathematics expert incorporated the MUST material on how to use the new textbook into MoE's presentation materials and presented it.

4.6.3 Pilot Monitoring and Evaluation by MUST

MUST project's monitoring and evaluation activities were implemented during the nine-month period from September 2022 to May 2023, when the new G9 and G10 textbooks and teacher's guides were put to piloting.[9] While the new materials were being piloted, the JICA Expert Team for MUST carried out five main activities at selected secondary schools to monitor the piloting, evaluate the effect of the new textbooks, and at the end, to formulate strategies for improving the utilization of the new textbooks.

The five main activities are:

1) Induction training and follow-up activities (including Subject Teachers Meetings)
2) Achievement Test No.1
3) Lesson observation and introduction of Rubric (lesson self-evaluation)
4) Unit-End Tests
5) Achievement Test No.2

[9] MUST monitoring and evaluation was carried out in parallel with MoE's monitoring and evaluation. MoE dispatched National Monitoring Teams to 53 pilot schools throughout Ethiopia during the period of December 18, 2022~January 5, 2023, to conduct lesson observations and teacher interviews. The results were then fed back to Textbook Developers in a workshop organized in February 2023.

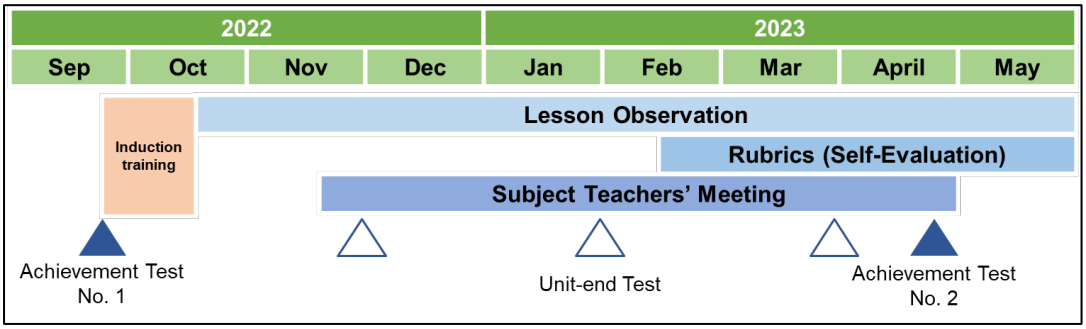


Figure 4.4 Five Main Activities by MUST for Pilot Monitoring and Evaluation

Target Schools

Addis Ababa Education Bureau (AAEB) selected three pilot schools and two non-pilot schools for the purpose of MUST monitoring and evaluation. They are shown in Table 4.12:

Table 4.12 Pilot Schools and Non-Pilot Schools Selected for MUST

School Name	Location (Sub-City)	Status	No. of Sections (G9 and G10 only)*	No. of Students (G9 and G10 only)*	No. of Math Teachers (G9 and G10 only)*
Kokebe Tsibah Secondary School	Yeka	Pilot	G9: 25 G10: 15	G9: 967 G10: 668	10
Beshale Secondary School	Lemi Kura	Pilot	G9: 12 G10: 9	G9: 978 G10: 518	7
Abyot Kirs Secondary School	Kirkos	Pilot	G9: 11 G10: 9	G9: 462 G10: 338	6
Tesfa Birhan Secondary School	Yeka	Non-pilot	G9: 12 G10: 7	G9: 523 G10: 322	6
Andode Secondary School	Lemi Kura	Non-pilot	G9: 6 G10: 6	G9: 420 G10: 383	6

* School data of EC2015 (2022/23).

Following parts describe the five activities and summarize the results of quantitative analyses of various data collected.

4.6.4 Induction Training by MUST

As the first activity of monitoring the piloting, an induction training was conducted for mathematics teachers at respective three MUST pilot schools, to introduce the new textbooks and how to use the new textbooks to conduct structured lessons. Table 4.13 shows the date and number of participants.

Table 4.13 Outline of MUST Induction Training

School Name	Date	No. of Participants
Kokebe Tsibah Secondary School	October 5, 2022	20 (G9: 5, G10: 5, G11: 4, G12: 6)
Beshale Secondary School	September 29-30, 2022	16 (G9: 4, G10: 2, G11: 5, G12: 5) Absent: 2 (G10: 1, G12: 1)
Abyot Kirs Secondary School	October 3-4, 2022	10 (G9: 3, G10: 2, G11: 3, G12: 2) Absent: 1 (G10: 1)

As is shown, in addition to G9 and G10 teachers, the training was also given to mathematics teachers for Grades 11 and 12, although no piloting will be implemented with those grades. The dates were carefully arranged with the schools to minimize the impact on weekday class time. The JICA Expert Team even offered to hold it on weekends but eventually the schools opted weekdays.

Given the significant changes in the structure of the textbooks, the training aimed to promote understanding of the "unitization" principle (one topic per lesson) incorporated in the new textbooks and the concept of A-D-E-E structured lessons using the new textbooks. Furthermore, the participants were guided to practice a structured lesson where students would always have time to solve problems on their own, through a hands-on session on lesson preparation and demonstration class. Throughout the entire sessions, the JICA Expert Team particularly emphasized that the teacher should spend 20 minutes for his or her explanation and 20 minutes for students' independent activity, and that students should always work on one evaluation item in each lesson. The contents of the introductory training are shown in Table 4.14.

Table 4.14 Sessions of MUST Induction Training

No.	Topic	Method
Session 1	Introduction of MUST and Objectives of This Training	Presentation
Session 2	Current Situation of Ethiopian Secondary Mathematics Education	Presentation
Session 3	What Has Changed in Textbooks?	Introductory presentation, Activity, Plenary
Session 4	Let's Practice a Lesson with New Textbooks! Part I: Let's experience a structured lesson! Part II: Let's make a teaching note! Part III: Preparation of lessons ~ Annal Plan, Weekly Plan and Teaching Notes Using the Unit Plans	Lesson demonstration, Activity Introductory presentation, Activity, Presentation, Plenary Introductory presentation, Activity, Lesson demonstration, Plenary
Session 5	Practical hints to conduct better lessons	Presentation

Since the training was held on weekdays at the three pilot schools, there was some concern that it would interfere with mathematics lessons of the teachers. However, the results of the questionnaire survey conducted at the end of each training showed generally positive responses in terms of satisfaction with the training and understanding of the training contents (Table 4.15).

Table 4.15 Participants' Evaluation of the Induction Training

Question Item	Average
Basic Information	
- Age	39
- Years of Teaching	17
Evaluation of the Training 1. Strongly Disagree 2. Disagree 3. Slightly Disagree 4. Slightly Agree 5. Agree 6. Strongly Agree	
- I understand the structure of new mathematics textbook	5.27
- I understand the lesson flow based on the new textbook	5.46
- I understand how to prepare weekly lesson plans and teaching notes	5.54
- I can take sufficient time for each student to solve evaluation items in a lesson	4.73
- I can evaluate students' learning in a lesson	5.11
- I think the new mathematics textbook is beneficial for students' learning	5.19
- I am satisfied with the training	5.62

Surprisingly, in October 2022, immediately after the training, we were able to observe in some lessons that students were given time to solve the problems by themselves as an apparent consequence of the above training. On the other hand, it was found that only few students were able to solve the problems on their own, and that some of the problems were still too difficult for the average students.

4.6.5 Lesson Observation

Purpose of Lesson Observation under Output 5

The purposes of lesson observation were to monitor the practice of structured teaching (A-D-E-E) using the new mathematics textbooks and to provide feedback to the teachers and the textbook developers.

Specifically, following activities were conducted under lesson observation:

- To record self-problem-solving time (class work time) on evaluation items (or exercise problems) and to check the level of students' understanding as to the given problem(s) during the given time;
- To give feedback to teachers to improve lesson practices (to carry out intended structured lessons) using the new textbooks;
- To obtain feedback from teachers on the implementation of the new textbooks and structured lessons, and examine effective ways of using the new textbooks in accordance with the actual situation in the next academic year; and
- To collect good examples of how to improve students' learning and implement structured lessons.

In addition to classes at pilot schools, MUST also observed some classes at non-pilot schools to know how the previous textbooks are being taught.

Duration of Lesson Observation under Output 5

The piloting of the new textbooks began in September 2022. Lesson observation under Output 5 was conducted over a seven-month period from November 2022 to May 2023.

Lesson Observation Tools

MUST developed a lesson observation sheet and used it when observing lessons to check if the lessons followed the structured lesson flow and to record the contents taught and duration of lesson components (Figure 4.5).

In addition to the lesson observation sheet, a table of "Rubric" was introduced in February 2023, as a tool that could be implemented on the Ethiopian side, which shall replace the post-observation reflection that had been conducted by MUST after each lesson observation. It is a matrix of criteria for teacher's self-assessment on structured lessons. Using the Rubric, teachers can conduct their own lesson reflection, and lesson observers can evaluate the lesson and provide feedback to the teacher.

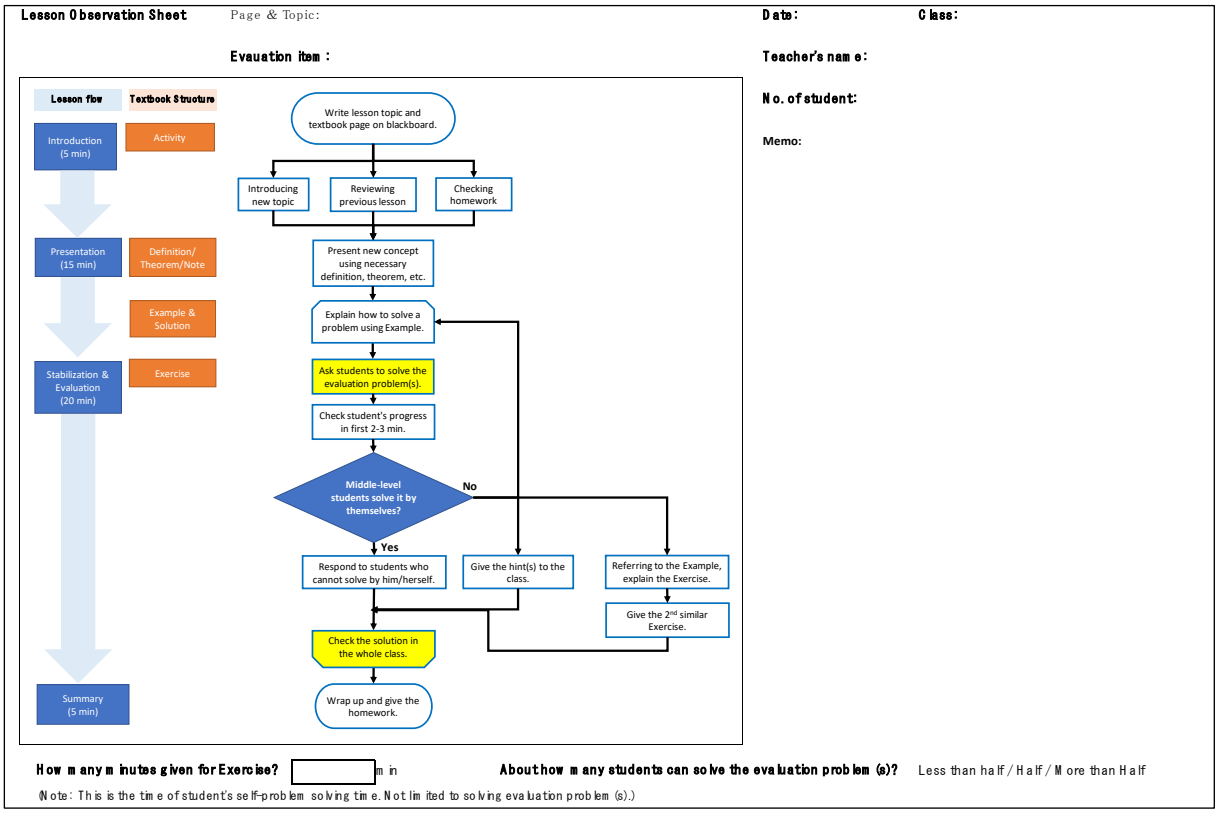


Figure 4.5 Lesson Observation Sheet

Number of Observed Lessons

In total, 103 lessons of Grade 9 and Grade 10 were observed during the period from November 2022 to May 2023 (Table 4.16).

Table 4.16 Observed Lessons by Month

Year	Month	Pilot School	Non-Pilot School	Total
2022	November	26	8	34
	December	16	-	16
2023	January	0	-	0
	February	19	2	21
	March	12	-	12
	April	1	-	1
	May	19	-	19
Total		**93**	**10**	**103**

Of these classes, three lessons in November 2022 and one lesson in April 2023 were observed together with Mathematics Expert at CDID/MoE. One lesson was observed with Curriculum Experts from Addis Ababa Education Bureau in April 2023; and two lessons in November 2022 and one lesson in April 2023 were observed with sub-city officer(s). As is seen, lesson observation by the Ethiopian counterpart side was limited.

Distribution of New Mathematics Textbooks for Piloting

The new textbooks for piloting were originally scheduled to be printed and distributed by MoE. However, due to a delay in their printing and distribution, MUST project distributed copies of the new textbooks in the ratio of one copy to one desk, which is 20~25 copies per section. Table 4.17 shows some details of the distribution.

Table 4.17 Photocopies of New Textbooks for Piloting Distributed by MUST Project

Grade	Unit*	Month of Distribution	Kokebe Tsibah (No. of copies)	Beshale (No. of copies)	Abyot Kirs (No. of copies)	Total
G9	U1', U1, U2	October 2022	400	300	210	**910**
	U3, U4, U5	January 2023	400	250	210	**860**
	U6, U7, U8	March 2023	400	250	220	**870**
	Total		**1200**	**800**	**640**	**2640**
G10	U1, U2, U3	October 2022	300	225	170	**695**
	U4, U5, U6	January 2023	300	190	170	**660**
	U7	March 2023	300	225	170	**695**
	Total		**900**	**640**	**510**	**2050**

Note: Unit numbers for G9 are of the draft version.

Main Findings from Lesson Observation

The result of the lesson observation over seven months is described below. It includes time given for student's self-problem solving, students' understanding of the exercises (evaluation items) dealt with during the given time, and the percentage of students bringing their textbook copies to the class.

Of the observed 103 lessons, 83 classes will be analyzed below. This number excludes lessons in non-pilot schools, lessons that were not regular classes (*e.g.*, homework check only, review only, Unit-End Test, etc.). The number of teachers included in this analysis is 20.

1) Self-Problem-Solving Time

Time for self-problem solving was measured as a duration from the time when the teacher gave an exercise problem as classwork until the time when the solution and answer was checked in the whole class. The Exercise question(s) given should basically be evaluation item(s). However, cases where the given

problems were other exercise problems or teacher's original problems were also included in the analysis.

Figure 4.6 below shows the average of self-problem-solving time given by respective teachers. Out of the 20 teachers, 10 teachers gave more than 10 minutes on average for this purpose.

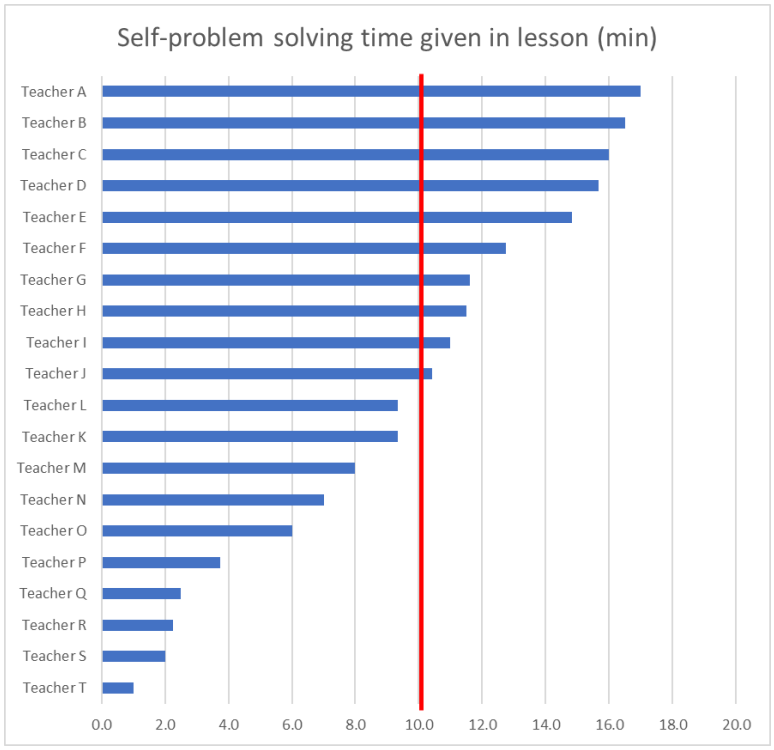


Figure 4.6 Average Self-Problem-Solving Time Given by Teacher

Looking at the same individual work time given per lesson, 36 of the 83 classes (43%) had at least 10 minutes of self-help time and 58 classes (70%) had more than 5 minutes of it. Generally, teachers gave evaluation items for exercise. Among the 36 classes with over 10 minutes' individual work time, 30 classes (about 83%) dealt with some evaluation items while in the 58 classes with more than five minutes, 40 (about 69%) classes solved evaluation items. It should be noted that in non-pilot schools, there was no time for individual work, and a form of group work was immediately implemented. In the pilot schools, such lessons were not observed.

2) Student's Understanding of the Topic

The level of student's understanding of the lesson topic was evaluated by how many students were able to solve the given problems. Rough ranges of "less than half," "about half," and "more than half" of the class were used for the judgement. Of the 36 lessons mentioned above, the number of lessons in which approximately half or more than half of the students were able to solve the given problem(s) was only nine lessons. Seven of those classes dealt with evaluation items.

In the lessons observed in December and onwards, when teachers became fully accustomed to the new textbooks, the structured lesson of A-D-E-E flow was observed in more than half of the classes. On the other hand, the following issues emerged with regard to the handling of self-problem-solving time:

- Many teachers were too busy checking the notebooks of students who had finished solving the problems early, and did not pay attention to those who could not do so;
- In some cases, the class was over without having time to check the solutions as a whole class;
- The time spent on one question in class work was too long; and
- The number of exercises given to students as class work was too small, so those who were able to solve them quickly had too much idle time.

To address those issues, the MUST project developed and introduced Rubric for self-assessment of

structured teaching practices (see Section 4.6.7 below). In addition, the project developed materials for subject teachers meetings to discuss the issues and find the solutions (to be described in Section 4.6.6 below).

Further, the lesson observations revealed that the majority of students had gotten into the habit of waiting for the teacher or other students to give them the correct answer. Even if teachers give students time to solve problems on their own, it was observed that only a small number of students start solving problems on their own. In many lessons, during the self-solving time, many students first spend time copying from the board or copying problems from the textbook, and then copy the answers from the notebooks of other students that the teacher has already checked or wait for the teacher's answers. In order to make it a habit for students to "try to solve the problems by themselves" during the self-problem-solving time, it is necessary, from the beginning of the school year, to give them necessary clues by handling examples and evaluation items in pairs, and to give them clear instructions to work individually.

3) Rate of Students Bringing Copies of New Textbooks

As noted above, copies of the new textbook for piloting were distributed to the G9 and G10 sections of the MUST pilot schools, at a rate of one copy per three students (one desk). Figure 4.7 below shows the percentage of students bringing the copies, observed during the period from November 2022 to May 2023. It can be seen from the figure that the rate of students bringing their own textbook copies has ranged from 26%, 1 copy for every 4 students, to 18%, 1 copy for every 6 students (or 2 desks). Even though teachers instruct students to bring their own textbooks and they use textbooks in their classes, they have not succeeded in getting students to bring all their own textbook copies to the lessons.

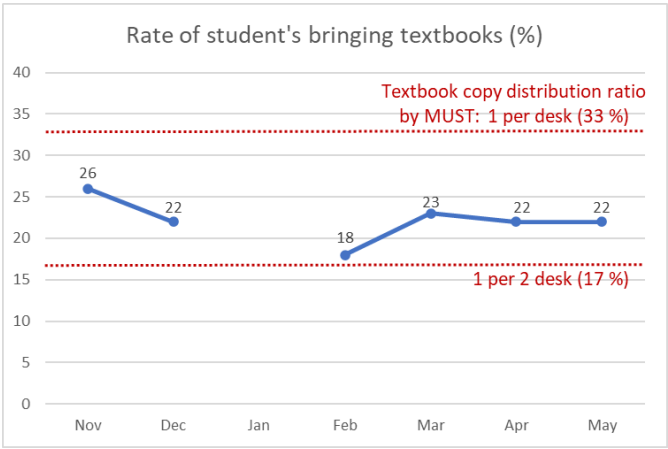


Figure 4.7 Rate of Students Bringing Textbooks

Of the 83 total observed lessons, 21 lessons had a rate of one-book-per-six-students (one book per two desks) or less. Of these lessons, there were three lessons in which no textbook copies were observed at all. In those classes, teachers conducted classes without referring to any textbook content at all.

Conclusion and Implications

Following conclusion and implications are drawn from the lesson observations.

1. Half of the 20 teachers analyzed in Grades 9 and 10 are able to provide at least 10 minutes of self-solving time, which is the standard for structured lessons, in accordance with the structure of the new textbooks. However, the students' level of understanding indicates that less than half of the students are able to solve the problems dealt with in the said lessons. For these teachers, the key to raising the level of understanding of the class as a whole is to use this independent solution time effectively and efficiently by focusing on the majority of students (who are struggling in solving) rather than on those who can. It is recommended that these teachers be given an opportunity to acquire the instructional skills indicated in the red box below (Figure 4.8), either in the form of ongoing on-the-job training or in-house training.

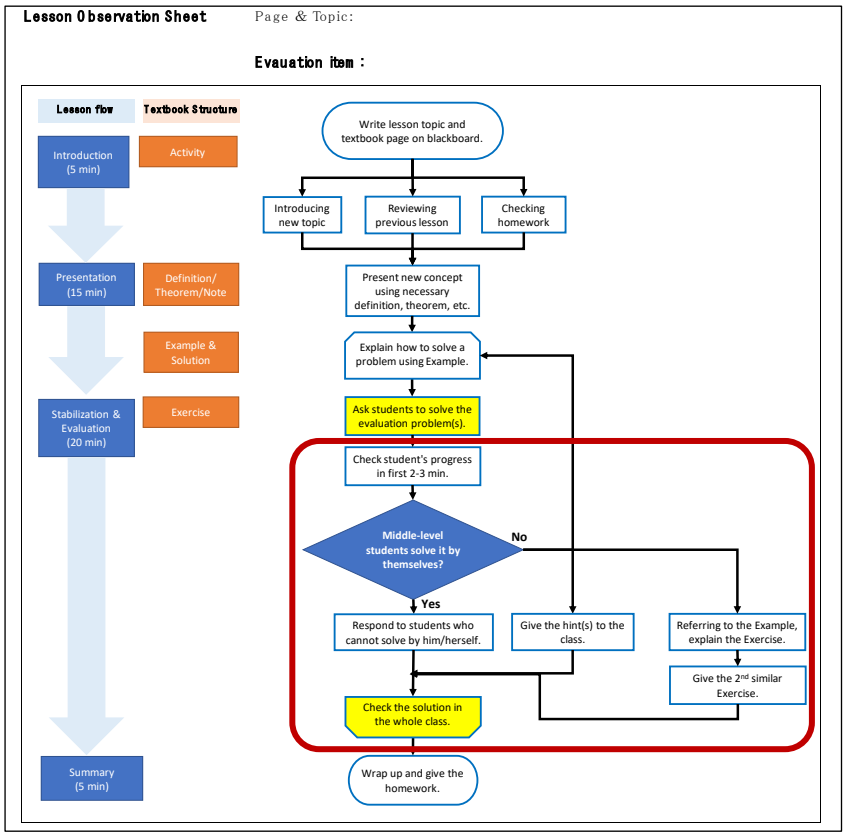


Figure 4.8 Instructional Skills Required for Teachers

In addition, in order to let the students have a habit to "try to solve the problem by yourself" during the self-problem-solving time, it is necessary to consistently practice structured lessons from the beginning of the school year with continuous efforts, by creating necessary clues by handling example and evaluation items in pairs, by giving clear instructions, etc.

2. On the other hand, the remaining half of the teachers have not been able to practice the structured lesson model even during the seven months of the piloting period. In addition to the induction training, they will need to continue practicing lesson preparation throughout the year, particularly lesson preparation based on the unit plans.

3. In terms of the percentage of students who bring their own textbooks to the lessons, class observations have shown that there should be a limitation to what one subject teacher can do alone. In order to rectify the situation where students do not bring their own textbooks to the class, it is necessary for school administrators to encourage students to bring their own textbooks, in collaboration with the education administrations.

4.6.6 Subject Teachers Meetings

The subject teachers meeting was planned as part of follow-up support for the teachers of the pilot schools. The meetings were originally intended to be held within the framework of Continuous Professional Development (CPD) introduced by the Federal Ministry of Education in 2008. However, upon gathering information on the status of the subject teachers meetings at each school, the JICA Expert Team for MUST came to realize that the CPD activities had become a mere formality (only written plans and reports). Nonetheless, through trial and error, the JICA Expert Team managed to hold one trial meeting at Kokebe Tsibah Secondary School, and three meetings at Abyot Kirs Secondary School by securing 30 minutes out of one-hour lunch break in cooperation with the school management.

The meetings aimed to discuss issues that were identified in the structured lesson practices (described above in Section 4.6.5) and in the administration of Unit-End Tests, and to derive solutions from the discussions. Thus, a case method was employed in the meeting materials. Following five teaching

materials were thus developed during the piloting period (Table 4.18). Note that those five topics have already been presented in the MUST Pilot School Experience-Sharing Workshop conducted on May 6, 2023, which brought mathematics teachers and school management teams together from the three pilot schools (for details see Section 4.6.10).

Table 4.18 Five Topics Developed for Subject Teachers Meetings

Case	Topic	Category
1	Time given to student's activity in class	Teaching method
2	Who needs your support more?	Teaching method
3	Effective use of Unit-End Tests (Scoring criteria)	Formative assessment
4	Effective use of Unit-End Tests (Students' difficulties/mistakes)	Formative assessment Teaching method
5	Measures to help Good Students learn more in class	Teaching method

Tables 4.19 and 4.20 below show some details of the subject teachers meetings held at the two schools.

Table 4.19 Subject Teachers Meeting at Kokebe Tsibah Secondary School

Date	Topic	No. of Participants
Nov. 30, 2022	1. Reflection on Unit-End Test result (G10 Unit 1) - Level of the Unit-End Test - Student's level of understanding 2. Reflection on own lesson - What do you try to do to improve the students' understanding during class?	6 persons Math teacher (G9-G12): 5 Yeka Sub-city officer: 1

Table 4.20 Subject Teachers Meeting at Abyot Kirs Secondary School

Date	Topic	No. of Participants
Jan. 12, 2023	Case 2: Who needs your support more?	11 persons Vice principal: 2 (Curriculum and TDP) Math teacher (G9-G12): 9
Feb. 16, 2023	Case 3: Effective use of Unit-End Tests (Scoring criteria)	6 persons Vice principal: 1 (TDP) Math teachers (G9-G12): 5
Mar. 28, 2023	Case 1: Time given to student's activity in class	3 persons Math teachers (G9-G12): 3

Through those trials, it became clear that in order to effectively conduct discussions incorporating the case method, it is necessary to have members who understand the content of the topic in advance and take on the role of facilitators to lead the discussions. In fact, in the second implementation at Abyot Kirs, the vice principal took on this role, and the discussions developed in line with the intentions embedded in the teaching materials.

4.6.7 Rubric as a Post-Lesson Reflection Tool

The MUST project developed the "Rubric" in February 2023 for teachers themselves and observers to evaluate the A-D-E-E lessons qualitatively. The Rubric is an evaluation tool for structured (A-D-E-E) lesson practice. Viewpoints and scales (evaluation criteria) for implementing A-D-E-E lessons are described in a table. It is expected that teachers will proactively improve their lesson practices. Following ten criteria are listed in the Rubric and the first three items are called "Step 1" (Table 4.21). The Rubric was introduced to MUST pilot schools in the second semester of EC2015 (2022/23) for enhancing teachers' self-reflection.

Table 4.21 Extract from the Rubric

Rubric	Criteria as to Level 1 (Exemplary)

Step 1	1	My lesson flow followed the textbook content (ADEE, DEE, or EE) and giving clear instructions such as: "Open the textbook page ##" and "Let's do exercise ##," etc.
	2	I gave 10 min and more for class work (Exercises) to all students.
	3	I gave the solutions and answers to the whole class after giving time; or My students solved the problems on the board to show to the whole class.
Step 2	4	In my lesson, at least one book per desk.
	5	My students opened and read the textbooks, solved the problems referring to the textbooks.
	6	I used all the evaluation items of Exercises and their paired Examples in the class.
	7	I gave an instruction to work on Exercises individually; or My students are accustomed to work on Exercises individually.
	8	Majority of my students worked on the given Exercises.
	9	I checked the understanding of not only those who could solve, but also those who were struggling to solve. I provided necessary support: Giving hints to the whole class; Giving explanation on 1st evaluation item as majority of my students cannot solve it.
	10	More than 50% of my students could solve the evaluation items on his/her own.

For those teachers motivated to improve their lessons, self-reflection using the Rubric may be effective to improve their teaching. However, it was difficult for unmotivated teachers to make them aware of their improvement points. To encourage these teachers to conduct self-reflection, we may need to give them feedback from the school leaders and supervisors as well as compare test results with other classes. Unfortunately, however, MUST was able to conduct few activities involving the school leaders and supervisors. It is expected that lesson observations using the Rubric will be conducted by the Ethiopian side in the future.

4.6.8 Achievement Test No.1 and No.2 (Summary)[10]

MUST conducted two achievement tests during the piloting of G9 and G10 textbooks.

Achievement Test No.1 (ACT1) was conducted at the end of October 2022 just before math lessons started in earnest in the new academic year. Its purpose was twofold:

1. To check whether the two groups of students (pilot and non-pilot school students) are statistically equivalent or not in terms of mathematics achievement; and
2. To collect baseline data to be compared with the results from Achievement Test No.2.

ACT1 consisted of 15 questions each for G9 and G10. The questions were all basic and selected from G5-G8 levels for G9 and from G5-G9 levels for G10.

Achievement Test No.2 (ACT2) was conducted six months later in April 2023. Its primary purpose was to collect endline data to be compared with the results from ACT1 to see the effects of the new textbooks. It consisted of 20 questions each for G9 and G10, covering following Units:

G9 Unit 1 Further on Sets
Unit 2 The Number System
Unit 3 Solving Equations

G10 Unit 2 Polynomial Functions
Unit 3 Exponential and Logarithmic Functions

Results of Achievement Test No.1

The numbers of participants of ACT1 were:

G9 420 (Pilot schools); 364 (Non-pilot schools); Total 784

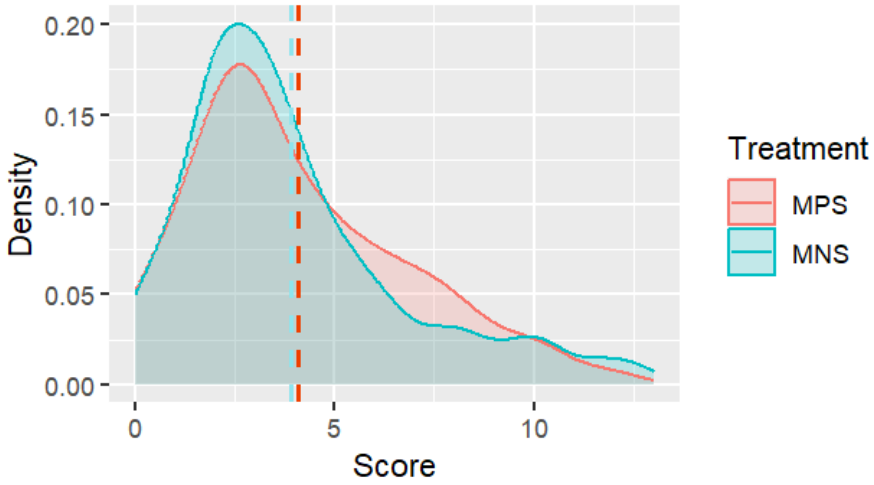
G10 400 (Pilot schools); 354 (Non-pilot schools); Total 754

The overall mean scores of ACT1 of G9 and G10 were 4.00 and 3.80 (out of 15), respectively. The mean

[10] For details, see Chapter 3 Results of Achievement Test No.1 and Chapter 6 Results of Achievement Test No.2 of *Report on the Pilot Monitoring and Evaluation*.

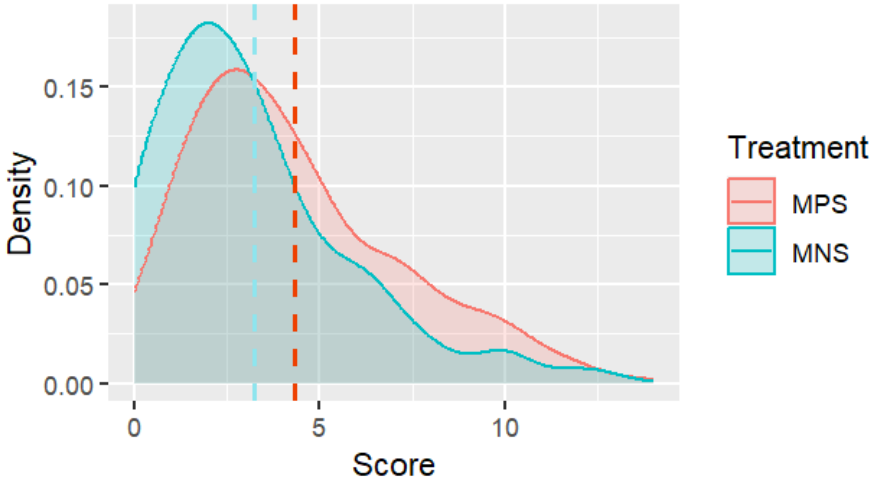
scores by pilot and non-pilot schools are 4.09 and 3.90 for G9 and 4.31 and 3.23 for G10. *t*-test shows that, for G9, there is no statistically significant difference between pilot and non-pilot schools but, for G10, there is. Therefore, when we compare the results from ACT1 and ACT2 later, we need to use caution in dealing with the G10 data while no such caution is necessary with G9 data.

Distribution of test scores in terms of probability density function is shown in Figure 4.9 for G9 and in Figure 4.10 for G10. Figure 4.9 shows that two distributions are almost identical for G9 but Figure 4.10 clearly shows that distribution of the scores of pilot school students is generally skewed to the right, that is, better than that of non-pilot school students.



Note: MPS stands for MUST pilot schools and MNS for MUST non-pilot schools.

Figure 4.9 Distribution of ACT1 Test Scores: G9



Note: MPS stands for MUST pilot schools and MNS for MUST non-pilot schools.

Figure 4.10 Distribution of ACT1 Test Scores: G10

Results of Achievement Test No.2

To evaluate the general effect of the new textbooks and new pedagogy, it is more advisable to compare the same groups that took part both in ACT1 and ACT2. This rigorous way enables us to detect the effect more precisely. The numbers of students who participated both in ACT1 and ACT2 and whose data were used for the general analysis were:

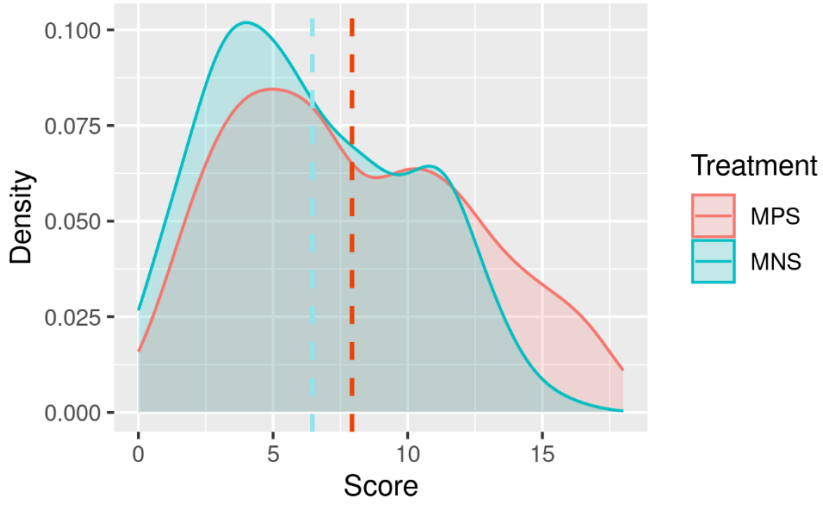
G9 409 (Pilot schools); 232 (Non-pilot schools); Total 641

G10 311 (Pilot schools); 247 (Non-pilot schools); Total 558

The mean score of the Achievement Test No.2 (ACT2) for G9 and for G10 were 7.40 and 6.45 (out of 20), respectively. The mean scores of pilot schools and non-pilot schools are 7.93 and 6.46 for G9 and 7.41

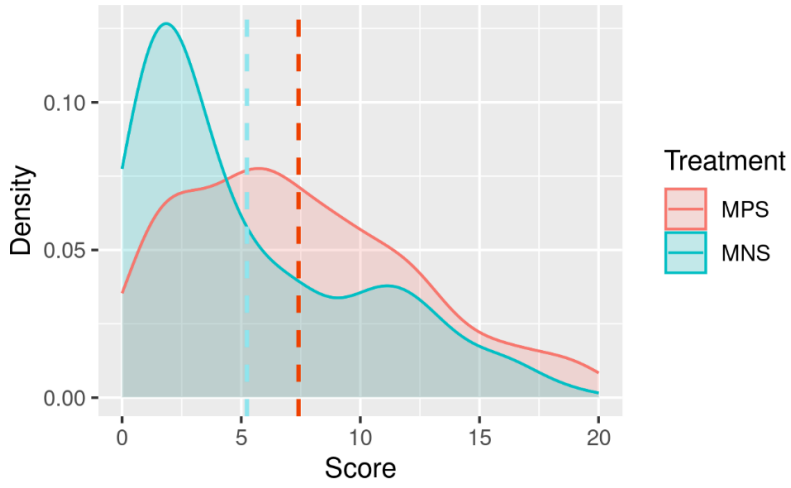
and 5.24 for G10. *t*-test shows that, for both grades, there is statistically significant difference between pilot and non-pilot schools.

Distribution of test scores of ACT2 for each grade in terms of probability density function is shown in Figures 4.11 and 4.12.



Note: MPS stands for MUST pilot schools and MNS for MUST non-pilot schools.

Figure 4.11 Distribution of ACT2 Test Scores: G9



Note: MPS stands for MUST pilot schools and MNS for MUST non-pilot schools.

Figure 4.12 Distribution of ACT2 Test Scores: G10

Thus we can safely conclude that, with both G9 and G10, students in pilot schools have significantly improved their performance than those in non-pilot schools since ACT1 was conducted. This improvement can be attributed to piloting in general and to the new textbooks and the new pedagogy in particular.

4.6.9 Unit-End Tests (Summary)[11]

Unit-End Tests (UT) were conducted when each Unit was completed with G9 and G10. Right after students learnt a certain Unit, the UT was given to them to compare the scores between pilot schools (that are using the new textbooks) and non-pilot schools (that are using the current textbooks). One UT consists of about ten basic questions, whose full mark was 20 points. Time allowed is 20 minutes. To

[11] For details, see Chapter 5 Results of Unit-End Tests of *Report on the Pilot Monitoring and Evaluation*.

avoid any advantage or disadvantage accruing to either group, question items were carefully selected from very basic ones.

Because teachers' progress in teaching has been unexpectedly slow, only two Units of G9 and two Units of G10 have so far produced a comparable set of data. The Units and the number of students who sat for the test are:

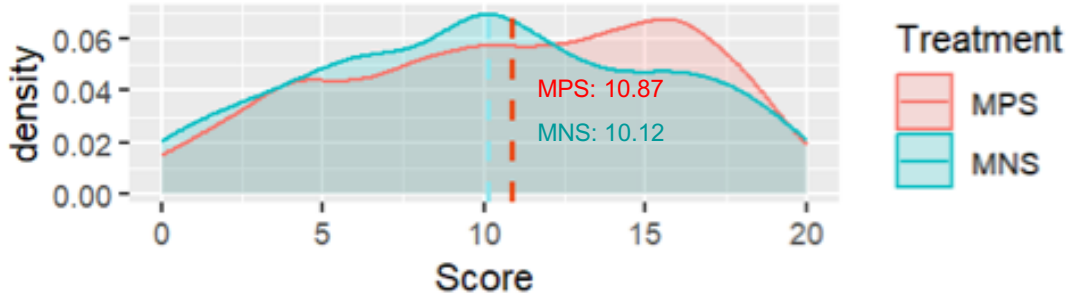
G9	The Number System	[Pilot: 1065, Non-Pilot: 751, Total: 1816]
	Further on Sets	[Pilot: 1150, Non-Pilot: 738, Total: 1888]
G10	Polynomial Functions	[Pilot: 992, Non-Pilot: 520, Total: 1512]
	Exponential and Logarithmic Functions	[Pilot: 1051, Non-Pilot: 585, Total 1636]

Results from G9

As to "The Number System," the mean score of the pilot schools was 10.87 while that of the non-pilot schools was 10.12. *t*-test showed a statistical difference between the means of pilot schools and non-pilot schools.

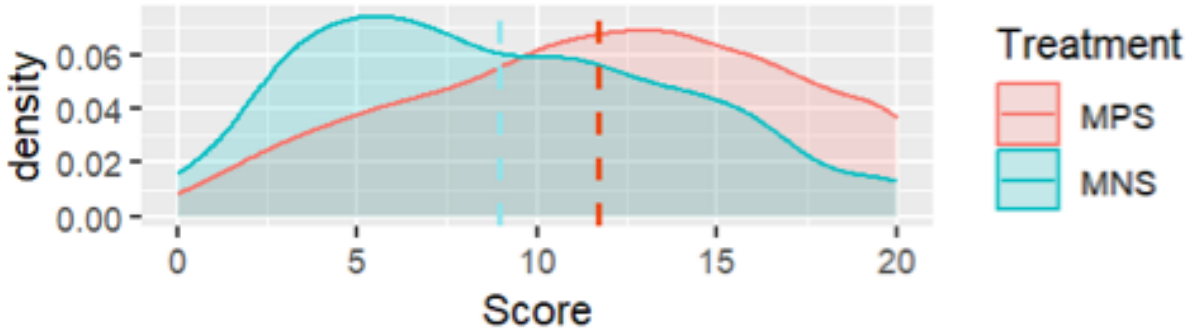
As to "Further on Sets," the mean score of the pilot schools was 11.69 while that of the non-pilot schools was 8.93. *t*-test showed a statistical difference between the means of pilot schools and non-pilot schools.

Figures 4.13 and 4.14 show the distribution of test scores in terms of probability density function.



Note: MPS stands for MUST pilot schools and MNS for MUST non-pilot schools.

Figure 4.13 Distribution of Test Scores: G9 The Number System



Note: MPS stands for MUST pilot schools and MNS for MUST non-pilot schools.

Figure 4.14 Distribution of Test Scores: G9 Further on Sets

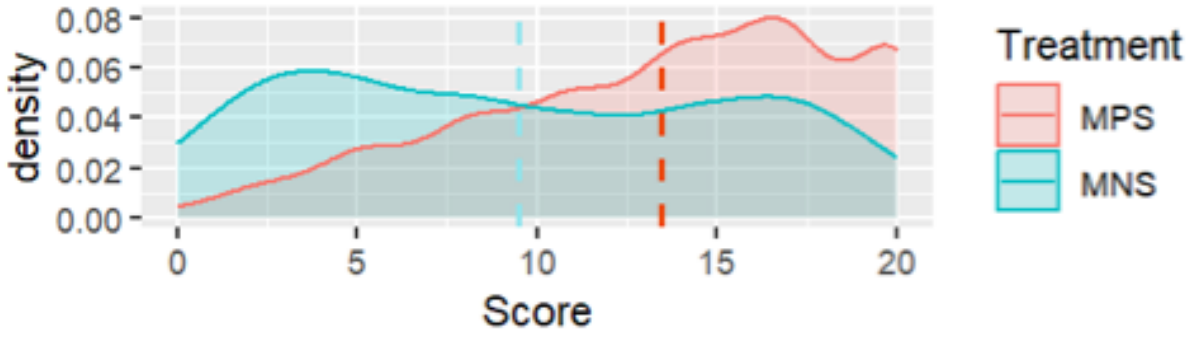
Results from G10

As to "Polynomial Functions," the mean score of the pilot schools was 13.37 while that of the non-pilot schools was 9.49. The result of student's *t*-test showed a statistical difference between the means of pilot schools and non-pilot schools.

As to "Exponential and Logarithmic Functions," the mean score of the pilot schools was 15.47 while that

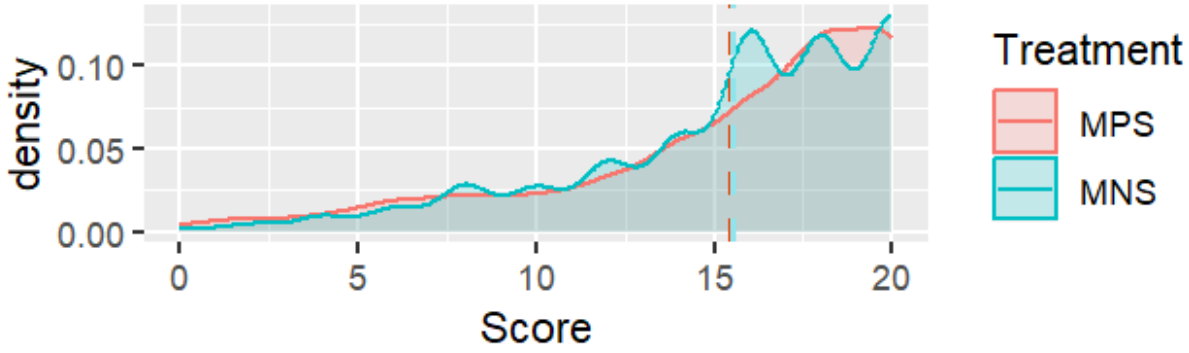
of the non-pilot schools was 15.53. A statistical difference was not observed between pilot schools and non-pilot schools.

Figures 4.15 and 4.16 show the distribution of test scores in terms of probability density function.



Note: MPS stands for MUST pilot schools and MNS for MUST non-pilot schools.

Figure 4.15 Distribution of Test Scores: G10 Polynomial Functions



Note: MPS stands for MUST pilot schools and MNS for MUST non-pilot schools.

Figure 4.16 Distribution of Test Scores: G10 Exponential and Logarithmic Functions

While non-pilot schools in Figure 4.15 show a pattern consistent with G9's distributions, non-pilot schools in Figure 4.16 show a quite different distribution from others. It is strongly suspected that there were irregularities in the administration of the Unit-End Test on "Exponential and Logarithmic Functions" with G10 students particularly at non-pilot schools.

Main Findings

The three Unit-End Tests (except G10's "Exponential and Logarithmic Functions") produced such score distributions that showed statistically significant differences between the students of pilot schools and non-pilot schools. As ACT1 results testified, the two groups of G9 showed no significant differences in their mathematics achievement at the beginning of piloting, whereas for G10 pilot school students showed slightly better performances than the non-pilot school counterparts. Given this, the significant differences thus observed in the Unit-End Tests may be attributed primarily to the new textbooks and the new teaching method introduced by MUST to best utilize the new structured textbooks.

4.6.10 Experience Sharing Workshops

The MUST project held following three workshops under Activity 5.8 (Conduct a nationwide workshop to share the MUST/MoE pilot experiences among stakeholders). Table 4.22 summarizes them.

Table 4.22 Workshops for Sharing Experiences

No.	Workshop	Date	No. of Participants

		Venue	
1	Workshop for sharing experiences with MUST pilot schools	May 6, 2023 Addis Ababa	Pilot school principals (7) Pilot school math teachers (33) Lemi Kura Sub-city Curriculum experts (2) AAEB Curriculum experts (2)
2	Workshop for sharing experiences with MUST non-pilot schools	June 24, 2023 Addis Ababa	Non-pilot school principals (4) Non-pilot school math teachers (16) Lemi Kura Sub-city Curriculum experts (4) Yeka Sub-city Curriculum experts (2) AAEB Curriculum experts (2) Model teachers from Pilot school math teacher (2)
3	Nation-wide workshop for sharing experiences with regional stakeholders	July 17-18, 2023 Adama	REBs Vice Head (6) REBs Curriculum directors (13) REBs Curriculum experts (14)

CDID and teachers from MUST pilot schools came to realize and confirm good points of A-D-E-E lessons through these workshops, which helped them raise self-awareness as resource persons. Following are potential resource persons who are willing to share their experiences with other schools and teachers:

- CDID expert who can instruct the characteristics of the new math textbooks and A-D-E-E lessons;
- AAEB and Lemi Kura sub-city experts who can explain and evaluate A-D-E-E lessons; and
- G9 and G10 math model teachers of MUST pilot schools who can demonstrate A-D-E-E lessons.

CDID will scale up the A-D-E-E lessons nationwide by mobilizing these resource persons toward the full implementation of the new curriculum. It is expected that the good practices including math department meetings and lesson observation tools will be shared with other departments of the Ministry such as TELDA and SIP, and utilized widely. Some details of each workshop will follow.

Workshop for Sharing Experiences with MUST Pilot Schools

As a final activity at the MUST pilot schools, a workshop was held in May in Addis Ababa to thank principals and teachers for their cooperation in the project and to share good practices among stakeholders. The workshop targeted G9-G12 math teachers and principals of the MUST pilot schools. Three sub-cities with jurisdiction over the pilot schools and AAEB were also invited, and only one sub-city and AAEB participated in the workshop.

At the opening, Natural Science Education Curriculum Desk Head of CDID expressed her gratitude to the pilot schools and stated that the Ministry would scale up the experiences of the MUST project. The CDID math expert moderated the sessions. In session 1, after the CDID math expert presented the characteristics of the new math textbooks and A-D-E-E lessons, participants shared their impression of A-D-E-E lessons. Here are some of their comments:

- The Ministry has learned that math teachers liked the idea of "unitization." (CDID)
- The new method to make students engaged is well addressed and it is being implemented in the pilot schools. "The 20 minutes for teacher and 20 minutes for students" is a good approach and students have started practicing the culture of being engaged. (AAEB)
- The students have become used to the new method and some teachers started implementing A-D-E-E lessons. (Lemi Kura Sub-city)
- I admit that teachers used to give students difficult questions, but now we have started to give simpler and basic questions and students are getting encouraged. (Math teacher)
- The Unit-End Test questions were very good because they were focused on basic items. (Math teacher)

The workshop sessions are listed in Table 4.23 below.

Table 4.23 Program of May Workshop

No.	Topic	Method
Session 1	Good practices of lesson observations: - Feedback from observers (MoE, AAEB, Sub-city) - Feedback from teachers - Feedback from MUST expert	Presentation
Session 2	Good practices of mathematics department meeting - Outline of mathematics department meeting - Let's try mathematics department meeting	Presentation Activity
Session 3	Lesson preparation using unit plan (confirmation of the process and sharing good points)	Activity
Session 4	Tentative results of Achievement Tests and Unit-End Tests	Presentation

Workshop for Sharing Experiences with MUST Non-Pilot Schools

In June, a half-day experience-sharing workshop was held for the MUST non-pilot schools in Addis Ababa. G9-G12 math teachers, principals as well as officials from sub-cities and AAEB participated in the workshop.

At the opening, Natural Science Education Curriculum Desk Head of CDID summarized what has been done up to now and the role MUST played during the whole process, and expressed her gratitude to the non-pilot schools and Addis Ababa Education Bureau. The CDID math expert moderated the sessions. The sessions conducted were all activity-based. The CDID math expert explained the characteristics of the new math textbooks after the related activity, and a model teacher from a pilot school demonstrated an A-D-E-E structured lesson and the other shared the pilot experience. The participants deepened their understanding of the new approach and practiced the lesson preparation using the unit plan. Following comments were given from non-pilot schools.

All the participants who responded the questionnaire (27 respondents) answered the contents of workshop were relevant to their work or any parts that were useful for their work. In addition, the respondents said that they have A-D-E-E approach the most useful (60%), followed by lesson preparation using unit plan (20%).

The workshop sessions are listed in Table 4.24 below.

Table 4.24 Program of June Workshop

No.	Topic	Method
Session 1	What has changed in the textbooks? - Comparison between old and new textbooks - Characteristics of the new math textbooks	Activity Presentation
Session 2	Let's experience a structured lesson! - Demonstration of a model lesson - Tips for the structured lessons	Demonstration Presentation
Session 3	Lesson preparation using unit plan	Activity

Nationwide Workshop for Sharing Experiences with Regional Stakeholders

As a conclusion of all MUST activities, a nationwide workshop was held in July in Adama to share the good practices with regional stakeholders. A total of 33 participants attended from all 13 REBs.

As the opening remark, CDID expert of Health and Physical Education expressed his appreciation of the MUST project's cooperation on behalf of the Natural Science Desk Head of CDID. The CDID math expert moderated the sessions. The seven sessions were conducted in two days and five of them were activity-based. A JICA expert presented the outline of MUST project and its outcomes using the results of the monitoring and evaluation at MUST pilot schools. CDID math expert explained the characteristics of the new math textbooks after the related activity, and a model teacher from a pilot school demonstrated an A-D-E-E structured lesson. The participants deepened their understanding of the new approach

through active discussion and practice for the lesson preparation and the mock math department meeting. CDID math expert, model teacher and AAEB math expert supported and facilitated the group works during the sessions. Finally, the A-D-E-E resource materials (A-D-E-E package) were introduced and shared with participants, and each region made a quarterly action plan for utilizing the A-D-E-E resource materials. Following feedback was given from regional stakeholders. All the participants who responded the questionnaire (31 respondents) answered they understood A-D-E-E structured lessons well (29%) or very well (71%). In addition, all regions evaluated the A-D-E-E resource materials as useful, and showed willingness to implement the A-D-E-E approach in their respective regions.

The workshop sessions are listed in Table 4.25 below.

Table 4.25 Program of July Workshop

No.	Topic	Method
Session 1	Outline of the MUST Project - General framework of MUST Project and summarized result of the project - Brief report on Pilot Monitoring and Evaluation of MUST Project	Presentation
Session 2	What has changed in the textbooks? - Comparison between old and new textbooks - Characteristics of the new math textbooks	 Activity Presentation
Session 3	Let's understand structured (ADEE) lessons with demonstration! - Demonstration of a model lesson - The explanation of the demo lesson	 Demonstration Presentation
Session 4	Lesson preparation using Unit Plan - How to use Unit Plan - Individual work and group work on chalk board writing plan - Presentation and feedback	 Introduction Activity Presentation
Session 5	Let's try a Mathematics department meeting! - Outline of Mathematics department meeting - Let's try Mathematics department meeting in each group!	 Introduction Activity
Session 6	Introduction and distribution of ADEE lesson package	Presentation
Session 7	Making an action plan by each region	Activity

4.6.11 A-D-E-E Structured Math Lessons for Ethiopian Students' Learning Improvement and Its Good Practices from MUST Pilot Schools

Activity 10 under Output 5 is to "make strategies to improve the learning achievement of students using Grades 9-12 textbooks at the classroom level." The resultant strategies are regarded as the summary of all Activities from 1 to 9, summarizing the findings and suggestions gained from the pilot monitoring. Thus, the MUST project initially planned to present "Learning Improvement Strategy for Ethiopia" based on the results of MUST pilot activities, and have it shared with regional stakeholders to disseminate the pilot experiences nationwide. This is also in line with the Project Purpose,[12] one of whose indicators is "The drafted learning improvement strategy for Ethiopia is presented to regional stakeholders." However, the JICA Expert Team was unable to reach a point of creating a system in which school leaders and sub-city officials support individual teachers' teaching. As a result, most of the pilot activities were done at the individual level and not at the organizational level. Because of this limitation, the title of the document no longer looked appropriate. Thus, it has been changed from "Learning Improvement Strategy for Ethiopia" to a more appropriate one, "A-D-E-E Structured Math Lessons for Ethiopian Students' Learning Improvement and Its Good Practices from MUST Pilot Schools." Although the title was changed to make its objectives clear to stakeholders, the positioning of the document remains the same as the draft strategy.

This document summarizes methods to implement the A-D-E-E structured lessons using the new mathematics textbooks and shows some good practices collected from the three MUST pilot schools. It describes the outline of a structured lesson, necessary internal activities to establish the A-D-E-E lessons at the school level, and responsibilities of stakeholders to help teachers make a habit of doing the A-D-E-

[12] Project Purpose is: Educational activities based on the new mathematics curriculum are introduced.

E lessons. In addition, following materials are compiled as attachments to the document for effective teacher training and school-based activities (Table 4.26). As a whole, they are also called "A-D-E-E Package."

Table 4.26 Resource Materials for Conducting A-D-E-E Lessons (A-D-E-E Package)

No.	Item	Description
1	A-D-E-E Structured Math Lessons for Ethiopian Students' Learning Improvement and Its Good Practices from MUST Pilot Schools	This document summarizes the implementation method of the A-D-E-E structured lessons using the new mathematics textbooks and shows its good practices from MUST three pilot schools. It is expected that the contents will be updated based on the results of REBs' practice/try-out.
2	Unit Plans (G9~G12)	List of Contents: It is a table that summarizes the contents that students will learn in the current grade according to the Ethiopian calendar. By looking at this, teachers are able to confirm which section of which Unit the student should be studying in which week of the month. 120 essential topics (related to minimum learning competencies stipulated in the syllabus) are mentioned for students to be able to study the contents of the syllabus in a balanced manner in a year. Unit Plans: These summarize all the lessons making up a Unit and the contents to be covered in each lesson. Examples and their corresponding exercises (called 'Evaluation items') are identified for each lesson. They are the minimum contents that must be covered in class.
3	Unit-End Tests (G9~G12)	The basic exercises are selected from the evaluation items. Teachers can use the Tests to confirm students' understanding/achievement at the end of the Unit.
4	Training Materials	These are for the following two types of teacher training. Induction training is to be conducted at the beginning of academic year, and follow-up training is to be implemented between two semesters of the year. Induction Training: To get prepared to conduct structured (A-D-E-E) lessons using new mathematics textbooks. The sessions cover: - What Has Changed in Textbooks? - Let's prepare ADEE lesson using Unit Plans! - How to use Unit-End Tests Follow-up Training: To conduct structured (A-D-E-E) lessons more effectively. The sessions cover: - Reflection using Rubric - Tips to improve your ADEE lessons - Let's try Mathematics department meeting! - How to use Unit-End Tests
5	Rubric as a Post-Lesson Reflection Tool	The expected lesson flow/teaching approach is described on the Rubric per level. The teachers can use this format for self-reflection, and the school leaders and administrative officers can use this for lesson observation.
6	Discussion Topics for Math Department Meetings	There are five topics related to mathematics and pedagogy to facilitate discussion in teachers' meetings.

This document was presented and shared with REBs at the MUST nationwide workshop in July 2023. In the workshop, REB curriculum officials practiced how to utilize these resource materials in their regions and will share the experience with zone and woreda educational stakeholders. After the full implementation of the new curriculum, the Ministry of Education and REBs are expected to utilize this to promote the A-D-E-E structured lessons with the new mathematics textbooks at secondary schools for the student's better learning.

4.6.12 Achievement of Output 5

Among the ten Activities instructed for Output 5, the first nine Activities were related to monitoring and

evaluation of piloting of G9 and G10 textbooks. They have been implemented mostly as planned and achieved their respective objectives. Among them, the two Achievement Tests and Unit-End Tests statistically verified that the new textbooks, combined with the new teaching method, have positive impact on students' achievement in Mathematics. The last Activity was to "make strategies to improve the learning achievement of students using Grades 9-12 textbooks at the classroom level," and this has produced a package of resource materials entitled "A-D-E-E Structured Math Lessons for Ethiopian Students' Learning Improvement and Its Good Practices from MUST Pilot Schools." This package has been shared with all REBs for their future use starting with the full implementation of the new curriculum and the textbooks in September 2023.

4.7 Public Relations

4.7.1 Articles for JICA Newsletter

The JICA Expert Team for MUST prepared articles on major activities as listed in Table 4.27 below. The articles were published both in JICA Ethiopia Facebook as well as on the website of JICA Headquarters.

Table 4.27 Articles about MUST Activities

No.	JICA Website	JICA Ethiopia Facebook	Topic
1	May 7, 2021	May 7, 2021	Baseline survey on Grade 9 to Grade 12 Mathematics in secondary schools in Addis Ababa, on April 19~24, 2021
2	May 13, 2021	May 11, 2011	MoE/JICA MUST Technical Workshop for Primary School Math Textbook Developers conducted, on April 26~28, 2021, Addis Ababa, Adama and Japan
3	August 4, 2021	August 2, 2021	Professionals from 5 Ethiopian universities trained on mathematical textbook development by MoE and JICA on July 12, 2021
4	November 1, 2021	October 28, 2021	Textbook Developers from four national universities participated in MUST Workshop on revision of draft 0 math textbooks of Grades 9 to 12, on October 16~18, 2021, Adama (1st workshop with Textbook Developers)
5	February 25, 2022	March 25, 2022	Math Textbook Developers from four national universities participated in MUST Workshop on revision of draft 1 math textbooks of Grades 9 to 12, on February 25~27, 2022, Addis Ababa (2nd workshop with Textbook Developers)
6	March 29, 2022	April 8, 2022	3rd Joint Coordinating Committee (JCC) Meeting for MUST Project held, revised math textbooks to be piloted in 98 Schools, on March 29
7	May 6, 2022	June 3, 2022	MUST's 3rd Workshop for G11-12 math Textbook Developers conducted, on May 6~8, 2022
8	-	July 4, 2022	4th MOE/JICA MUST Workshop for Grades 11-12 math Textbook Developers started, on June 17, 2022
9	-	October 6, 2022	MUST Project conducts 5th Workshop with Grades 9-12 math Textbook Developers on August 26~28, 2022
10	-	November 13, 2022	Ms. Imoto, JICA's Senior Vice President, visited Abyot Kirs Secondary School
11	-	August 1, 2023	MoE and JICA conduct National Experience Sharing Workshop for new math textbooks

4.8 Joint Coordinating Committee Meetings

4.8.1 Third Meeting

MoE, in cooperation with JICA, convened the third Joint Coordinating Committee meeting on March 29, 2022. The meeting was chaired by Dr. Theodros Shewarget, Director General. The meeting discussed following agenda: 1) to review MUST progress from 2021 until 2022; and 2) to review and decide MUST activity plan from 2022 until 2023. The conclusions are summarized in the Minutes, which is reproduced

in Appendix 9.

4.8.2 Fourth Meeting

MoE, in cooperation with JICA, convened the fourth Joint Coordinating Committee meeting on November 24, 2022. Since State Minister and Chief Executive Officer of MoE were both on duty abroad, Chief Executive Officer delegated Ms. Zafu Abraha, Natural Science Education Curriculum Desk Head of CDID, to chair the meeting and sign the minutes of the meeting. The meeting discussed following agenda: 1) to review MUST progress from March 2022 to November 2022; and 2) to decide MUST activity plan from December 2022 to August 2023. For discussions see the Minutes in Appendix 10.

4.8.3 Fifth Meeting

MoE, in cooperation with JICA, convened the fifth Joint Coordinating Committee meeting on May 9, 2023. The meeting discussed following agenda: 1) to review MUST progress from December 2022 to April 2023; and 2) to decide MUST activity plan from May 2023 to August 2023. For the Minutes of Discussion, see Appendix 11.

4.8.4 Sixth Meeting

MoE, in cooperation with JICA, convened the sixth Joint Coordinating Committee meeting on July 24, 2023. The meeting discussed following agenda: 1) to review "Report on the Pilot Monitoring and Evaluation"; 2) to review "Project Completion Report"; 3) to confirm Project's achievements; and 4) to discuss the way forward after MUST. This meeting officially concluded the MUST project. For the Minutes of Discussion, see Appendix 12.

5 ACHIEVEMENT OF PROJECT OBJECTIVES

So far in Chapter 4, we have summarized Activities MUST has done in accordance with the specifications given in the PDM. Those Activities were intended to achieve five Outputs and, eventually, project objectives. This chapter, therefore, evaluates how much the project objectives and Outputs have been achieved with respect to their Objectively Verifiable Indicators, also specified in the PDM. In addition, Section 5.5 will show the results of evaluation with respect to OECD DAC Evaluation Criteria (Relevance, Coherence, Effectiveness, Efficiency, Impact and Sustainability).

5.1 Project Goals, Purposes and Outputs

The Project Design Matrix (PDM) specifies Project Goals, Purposes and Outputs as follows:

Super Goal	The learning performance in mathematics is improved
Overall Goal	Educational activities based on the new mathematics curriculum are promoted
Project Purpose	Educational activities based on the new mathematics curriculum are introduced
Output 1	Quality of the mathematics curriculum documents (flow charts, MLCs, and syllabi) is assured
Output 2	Technical recommendations, based on the situational analysis of classroom practices, are incorporated to Grades 9-12 textbook editing strategies and M&E
Output 3	The capacity in developing Grades 1-8 mathematics teaching materials are improved through technical WS
Output 4	The quality of Grades 9-12 textbook contents is improved
Output 5	Strategies for improving the utilization of Grades 9-12 textbooks are proposed based on monitoring and evaluation

5.2 Objectively Verifiable Indicators

For each goal, purpose and output, a few Objectively Verifiable Indicators are specified as well. They are:

Super Goal		Results of the national examination on mathematics are improved compared to those of 2020
Overall Goal	1.	New Grades 9-12 math textbooks are distributed and used in more than 75% of the secondary schools after full implementation of the new curriculum
	2.	Strategies for learning improvement for Grades 9-12 in Ethiopia are developed
	3.	New Grades 1-8 math textbooks have been produced by REB based on new syllabus in all regions after full implementation of the new curriculum
Project Purpose	1.	New Grades 9-12 math textbooks are authorized by MoE
	2.	The drafted learning improvement strategy for Ethiopia is presented to regional stakeholders
	3.	60% of participants of the technical WS have applied the knowledge learned during the WS in order to produce Grades1-8 textbooks
Output 1	1.	Three curriculum documents are approved by MoE
Output 2	1.	Five directions (viewpoints) for draft textbook revision are approved by MoE
Output 3	1.	60% of participants of the technical WS have learned new knowledge for textbook development to apply in developing Grades 1-8 mathematics textbooks

Output 4

1. Improvements are observed in the final version of textbooks compared with the Draft 0 textbooks

1-1. 100% of units/sub-units are corrected and improved in terms of layout, math expressions, figures, graphs, etc.

1-2. 100% of units/sub-units are "unitized" in the lesson structure

1-3. Evaluation items (basic problems) are included in Exercises

Output 5

1. Students are provided with over 10 minutes to solve exercise in one lesson when using the new textbooks
2. Results of Math achievement test/Unit test at MUST pilot schools with the new textbooks and MUST intervention is better than non-pilot schools with the previous textbooks
3. Draft learning improvement strategies for Ethiopia is proposed

5.3 What MUST Has Achieved

Super Goal, Overall Goal and Project Purpose stated above are rather abstract to describe what MUST has strived to achieve. Put in more concrete terms, MUST has basically pursued to assist CDID in assuring the quality of curriculum documents for G1-G12 and textbooks and teacher's guides for G9-G12 in mathematics. After its four and a half years of operation, MUST has made three main achievements:

1) Successful introduction of "unitization" or, in other words, A-D-E-E structured textbooks and lessons (first of its kind in Ethiopia);[13]

2) Verification of the positive effect of the structured textbooks and lessons on students' better achievement in mathematics; and

3) Development of a set of resource materials to facilitate teachers to conduct A-D-E-E lessons using the new textbooks, and its nationwide introduction.

It is hoped that the new textbooks will be nationally utilized, the new pedagogy will be widely practiced, and that the students will perform better in mathematics.

5.4 Achievement with Respect to Objectively Verifiable Indicators

Following is a summary of project achievement of respective goals, purposes and outputs evaluated with respect to the Objectively Verifiable Indicators.

5.4.1 Super Goal

Statement	Objectively Verifiable Indicators	Achievement
The learning performance in mathematics is improved	Results of the national examination on mathematics are improved compared to those of 2020	- To be verified 10 years later

5.4.2 Overall Goal

Statement	Objectively Verifiable Indicators	Achievement
Educational activities based on the new mathematics curriculum are promoted	1. New Grades 9-12 math textbooks are distributed and used in more than 75% of the secondary schools after full implementation of the new curriculum	- To be verified 3 to 5 years later
	2. Strategies for learning improvement for	- Strategies have

[13] Director of CDID mentioned in a meeting with JICA Senior Vice President in November 2022 that she would apply the A-D-E-E structure to Physics textbooks, too.

	Grades 9-12 in Ethiopia are developed	been drafted; To be verified 3 years later
	3. New Grades 1-8 math textbooks have been produced by REB based on new syllabus in all regions after full implementation of the new curriculum	- Achieved

5.4.3 Project Purpose

Statement	Objectively Verifiable Indicators	Achievement
Educational activities based on the new mathematics curriculum are introduced	1. New Grades 9-12 math textbooks are authorized by MoE	- Achieved
	2. The drafted learning improvement strategy for Ethiopia is presented to regional stakeholders	- Achieved (see Section 4.6.10)
	3. 60% of participants of the technical WS have applied the knowledge learned during the WS in order to produce Grades1-8 textbooks	- Achieved (see Section 4.4.4)

5.4.4 Output 1

Statement	Objectively Verifiable Indicators	Achievement
Quality of the mathematics curriculum documents (flow charts, MLCs, and syllabi) is assured	1. Three curriculum documents are approved by MoE	- Achieved (see Section 4.2.3)

5.4.5 Output 2

Statement	Objectively Verifiable Indicators	Achievement
Technical recommendations, based on the situational analysis of classroom practices, are incorporated to Grades 9-12 textbook editing strategies and M&E	1. Five directions (viewpoints) for draft textbook revision are approved by MoE	- Achieved (see Section 4.3.3)

5.4.6 Output 3

Statement	Objectively Verifiable Indicators	Achievement
The capacity in developing Grades 1-8 mathematics teaching materials are improved through technical WS	1. 60% of participants of the technical WS have learned new knowledge for textbook development to apply in developing Grades 1-8 mathematics textbooks	- Achieved (see Section 4.4.4)

5.4.7 Output 4

Statement	Objectively Verifiable Indicators	Achievement
The quality of Grades 9-12 textbook contents is improved	1. Improvements are observed in the final version of textbooks compared with the Draft 0 textbooks	- Achieved
	1-1. 100% of units/sub-units are corrected and	- Achieved

	improved in terms of layout, math expressions, figures, graphs, etc.	
	1-2. 100% of units/sub-units are "unitized" in the lesson structure	- Achieved
	1-3. Evaluation items (basic problems) are included in Exercises	- Achieved

5.4.8 Output 5

Statement	Objectively Verifiable Indicators	Achievement
Strategies for improving the utilization of Grades 9-12 textbooks are proposed based on monitoring and evaluation	1. Students are provided with over 10 minutes to solve exercise in one lesson when using the new textbooks	- Achieved in about 45% of lessons (see Section 4.6.5)
	2. Results of Math achievement test/Unit test at MUST pilot schools with the new textbooks and MUST intervention is better than non-pilot schools with the previous textbooks	- Achieved (see Sections 4.6.8 and 4.6.9)
	3. Draft learning improvement strategies for Ethiopia is proposed	- Achieved (see Section 4.6.11)

5.5 Evaluation with Respect to OECD DAC Evaluation Criteria

The OECD DAC evaluation criteria are as follows: Relevance, Coherence, Effectiveness, Efficiency, Impact and Sustainability. The project's achievements will be evaluated with respect to those six criteria and indicated as either "Very high," "High," "Low," or "Very low." Following are brief descriptions of the evaluation results.

5.5.1 Relevance

Relevance is very high.

MUST project was conceived in 2018 to assist MoE in its historic endeavor to initiate a new round of comprehensive curriculum reform in about one decade. Since MoE did not have a sufficient number of qualified experts to carry out or supervise this colossal task but did not want to commission foreign partners to do the job on their behalf, MUST project as a technical cooperation project was a right vehicle to provide technical support MoE needed. The project successfully assisted MoE to assure the quality of curriculum documents for mathematics of G1 to G12, and the textbooks and teacher's guides for mathematics of G9 to G12.

5.5.2 Coherence

Coherence is very high.

Curriculum and textbook development are two main components of JICA's "Comprehensive Approach for Learning Improvement."[14] Among the four areas of the "Learning Cycle," as far as Ethiopia is concerned, JICA already implemented projects in teacher's in-service training (SMASEE) and improvement of assessment (LAMS), on whose achievements this MUST project was founded, completing the "Learning Cycle." This MUST project will also contribute to Goal 4 of SDGs: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. One of JICA's priority efforts to achieve the goal is "Improvement in children's learning," where JICA will pay attention to "consistency

[14] "This approach enables us to provide comprehensive solutions with consistent interventions throughout (1) curriculum, (2) textbooks and teaching and learning materials, (3) lessons and (4) assessment, so that the Learning Cycle is strengthened. Specifically, JICA's support to provide comprehensive solutions will be in the following areas: (1) development and revision of systematic and consistent curriculum, (2) development of textbooks which are consistent with the curriculum and learning materials for children's basic skills acquisition, (3) teacher professional development through pre-service and in-service teacher training and development/revision of teachers' guides and 4) improvement of assessment which is consistent with other areas of the learning cycle." JICA. (2015). *JICA Position Paper in Education Cooperation*. p.8.

and coherence between curriculum, textbooks, teaching and learning materials, lessons, and assessment."[15] Another development partner who has assisted MoE in the curriculum reform is UNICEF. UNICEF's support and MUST project nicely dovetailed each other, with UNICEF dealing with the general curriculum development of all subjects while MUST focusing on very technical aspects of mathematics only. In promoting the A-D-E-E structure for the first time in Ethiopia, MUST project referred to other development partners' experiences and results documented in their publications to ensure its international coherence.[16]

5.5.3 Effectiveness

Effectiveness is high.

Project purpose, "Educational activities based of the new mathematics curriculum are introduced," has been achieved at the three pilot schools in Addis Ababa. At those schools, MUST project not only piloted the new G9 and G10 textbooks successfully with significant impact but also conducted various activities to improve the lessons using the new textbooks. The achievement, however, is with two reservations.

First, the piloting was completed as planned because MUST project distributed photocopies of the new textbooks to the pilot schools. Despite its plan, MoE could not provide the new textbooks for piloting for unknown reasons. Thus, one Important Assumption specified in the PDM, "Teaching and learning materials based on the new math curriculum are accessible for teachers and leaners," was not met. MUST project's emergency operation made the piloting possible at its three pilot schools.

Second, not all activities tried by MUST at the pilot schools have proved possible. The trials have also revealed systemic problems inherent in the educational administration of Ethiopia. Accordingly, adjustments have been made to the original ideas and the results are compiled into the "A-D-E-E Package," the strategies for improving the utilization of the new textbooks. Those adjustments have to be tested further in practice for their practicability.

5.5.4 Efficiency

Efficiency is high.

As far as project costs and duration are concerned, no significant increase from the original plan was made. In that sense, overall efficiency can be judged very high.

However, we have to consider two aspects. One is the insufficient input from the MoE side. Counterpart personnel to work for the MUST project has been limited. To begin with, the textbook developers were all recruited from outside sources and no one from MoE worked as one. Also, involvement of experts outside CDID was not active throughout the project. Consequently, technical inputs from the JICA experts to Ethiopian experts can never be fully effective.

The other aspect is with the output prescribed in the previous PDM. The PDM was completely revised near the end of Period 1 due to a shift in MoE's policy. As a result, the main output of Period 1, sample Lesson Support Materials for G1, G4 and G7, could not be fully utilized in Period 2. Resources put in this undertaking was thus partly wasted.

Therefore, overall efficiency of the project should be judged high. MUST project as a whole, however, proved very cost efficient, achieving the Outputs as specified in the PDM without much additional input even in the very hard and irregular situations that lasted for about two years because of COVID-19 and insecurity in the north.

5.5.5 Impact

Impact can be high.

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[15] JICA. (n.d.). *JICA's position paper on SDGs: Goal 4*. p.4-3.

[16] UNICEF. (2020). Structured pedagogy: For real-time equitable improvements in learning outcomes (UNICEF Eastern and Southern Africa Working Paper 2020). Nairobi: UNICEF Eastern and Southern Africa Regional Office
Retrieved from https://www.unicef.org/esa/media/7511/file/ESA-Structured-Pedagogy-2020.pdf
USAID. (2019). Promoting successful literacy acquisition through structured pedagogy. Chevy Chase, MD: Global Reading Network.
Retrieved from https://www.edulinks.org/sites/default/files/media/file/Structured%20Pedagogy_REACH%20Nov%202019.pdf
Molina, E., Pushparatnam, A., Rimm-Kaufman, S., & Wong, K.K. (2018). Evidence-based teaching: Effective teaching practices in primary school classrooms (Policy Research Working Paper 8656). World Bank Group.
Retrieved from https://documents1.worldbank.org/curated/en/552391543437324357/pdf/WPS8656.pdf

MUST project has conducted few activities outside the three pilot schools in Addis Ababa and the new textbooks have yet to be distributed nationwide. Therefore, it is impossible or premature to judge whether the Overall Goal, "Educational activities based on the new mathematics curriculum are promoted," has been or will be achieved outside the three MUST pilot schools. Nonetheless, after MUST project is finished, it is expected that the Overall Goal can be achieved throughout Ethiopia if MoE provides the textbooks as planned and the REBs properly train the math teachers utilizing the "A-D-E-E Package" prepared by MUST. Once the Overall Goal is achieved, the Super Goal, "The learning performance in mathematics is improved," is highly likely to be achieved, too.

Nonetheless, it will be modest to observe this. The new textbooks for G9 and G10 developed through MUST have proved to be able to improve students' achievement in mathematics when combined with the new teaching method, also developed by MUST. As far as MUST piloting is concerned, the project has proved very effective, more so than anticipated, with statistically significant differences. However, it is not certain yet if the new textbooks (including those for G11 and G12) will still be effective in other areas than Addis Ababa where the environment is so different. This aspect should be evaluated in 2023/24 when the new textbooks are distributed and put into use at secondary schools throughout Ethiopia.

5.5.6 Sustainability

Sustainability is neither high nor low.

In terms of sustainability, four most critical components should be 1) budget for textbook printing, 2) budget for teachers' training, 3) technical support for teachers' training and continuous professional development, and 4) Ethiopian resource persons who are able to disseminate the new concepts throughout the country.

MoE has secured budget to print the initial batch of textbooks in the ratio of 1 textbook to 4 students and plans to print the rest in stages. It is strongly recommended and expected that the ratio of 1 textbook to 3 students should be minimally realized as soon as possible to effectuate the positive impact of the new textbooks nationwide. JICA is willing to contribute to this endeavor financially, though its amount is limited.

REBs, who are responsible for implementing teachers' training, are unanimously complaining of a severe dearth of budget for such activities. If teachers' training is curtailed due to lack of budget, the new teaching method will not be fully introduced to the teachers and the impact of the new textbooks should necessarily be limited. MoE's financial support to this aspect is needed and strongly expected while REBs need to come up with cost-effective activities possible within their own resources.

Technical support for teachers' training and continuous professional development should also come from MoE and the Ethiopian resource persons affiliated with MUST. MoE, particularly TELDA, should be responsible for mobilizing the resource persons to assist REBs in the coming new academic year and beyond. The technical support can be partially provided by a new JICA advisor succeeding MUST.

Resource persons can be grouped into three groups. The first group of resource persons is math teachers (including school principals). Around 50 of them at the three MUST pilot schools at least know about the A-D-E-E structured lessons, and about 20 G9 and G10 teachers have practiced the new teaching method to varying extent. A few of them can become qualified trainers on the new teaching method.

The second group is education officials at national and regional levels. Their involvement in MUST project has been very limited for various reasons. Nonetheless, impact on those small number of officials who actively participated in MUST monitoring activities can be evaluated very high. Also, judging from the national experience sharing workshop held in July 2023 as one of the last activities by MUST, REB officials may be highly motivated to promote the new textbooks and the new teaching method in their respective regions. Therefore, we can safely expect that those educational officials will be active resource persons to disseminate the project outputs.

The third group, which is not mentioned in the PDM, is the 18 textbook developers. Even though they are not official counterpart of this project, they, nonetheless, benefitted greatly from the MUST project digesting the concepts of "unitization" and "A-D-E-E structure." If the next chance of textbook development (and curriculum development) is given, many of them are very willing to take that opportunity. They have become a pool of qualified Ethiopian experts who can revise the new textbooks (and curriculum)

on the one hand, and, on the other, who can be mobilized as trainers.

Qualified resource persons are thus available but budget to mobilize them and the trainees would be again the main constraint.

Overall, sustainability, the most difficult aspect to achieve, shows some positive clues while being hampered by deep-rooted constraints inherent in the system. To the best of our knowledge, therefore, sustainability is evaluated neither high nor low.

6 STEPS FORWARD

The Ministry of Education has thus accomplished its curriculum reform initiated in 2019 under the leadership of CDID. It was a wide-ranging, large-scale undertaking, covering all subjects of all grades from kindergarten to G12. As far as MUST is concerned, the new G9-G12 mathematics textbooks and teacher's guides, the main targets of MUST, can be judged considerably improved from the current textbooks and guides. If the curriculum reform is successful, MoE's endeavor should not stop there. There remain a few new tasks to be tackled by MoE in the coming years. With the new, improved textbooks and teacher's guides in hands, what tasks should MoE tackle next? Some elaborations will follow.

6.1 Distributing Textbooks

Numbers involved in textbook distribution are huge. In 2021/22, there were 3,867,463 students enrolled at secondary schools (G9~G12). They took 12 subjects (G9 and G10) or 10 subjects (G11 and G12). In total, about 24 million textbooks were registered nationally for secondary level, which means each secondary student had 6.3 textbooks on average. With regard to mathematics, 2,296,162 textbooks were nationally distributed with a textbook-to-pupil ratio of 0.6.[17] Secondary school enrollment is steadily increasing, with an average annual growth rate of 9.7% in the past five years.[18] This means that, theoretically speaking, roughly 4 million textbooks of all subjects are additionally required each year. Financial implications are enormous.

Since all previous textbooks of all subjects must be replaced with the new textbooks all at once in September 2023, MoE needs a considerable amount of budget and time to accomplish it. In view of various constraints, however, it would be a realistic approach to provide the new textbooks gradually in a few years.[19] As MUST pilot schools have proved, the ratio of one textbook to three students (1:3 TPR) might be the minimally acceptable standard.[20] If MoE pursues the ratio of one textbook to four students (1:4 TPR) due to initial budget constraint, it should be accepted as a temporary measure. But printing of additional copies must be pursued by all means.

6.2 Implementing the MUST Outputs Other Than Textbooks

MUST project has produced some notable outputs other than the textbooks and teacher's guides. They are the Rubric and the A-D-E-E Package, both targeting the teachers to supplement the teaching materials.

The Rubric is a tool for teachers' self-reflection of their daily lessons. It can also be used by school leaders, supervisors and officials when observing and evaluating lessons. During the MUST monitoring of piloting, the Rubric was put to trial with teachers largely with support from JICA experts. Unfortunately, it was not often that school leaders and supervisors conducted lesson observation on their own using the Rubric. It is expected that lesson observation using the Rubric will be routinely conducted by the Ethiopian side in the future.

The A-D-E-E package ("A-D-E-E Structured Math Lessons for Ethiopian Students' Learning Improvement and Its Good Practices from MUST Pilot Schools") is a collection of resource materials developed by MUST as auxiliary products of the textbooks (Unit Plans, Unit-End Tests) or as supporting materials for teachers' activities (Training Materials, the Rubric, Discussion Topics for Math Department Meetings). They are all geared to support teachers to conduct A-D-E-E structured lessons in a better way. When the new textbooks are officially put in use in September 2023, those materials will be in great demand by math teachers throughout Ethiopia. REBs, Zones and Woredas should utilize the package to its full extent and support the teachers who are not familiar with the A-D-E-E approach.

To make future teachers familiar with the A-D-E-E approach, it is recommended that the A-D-E-E

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17 Ministry of Education. (2023). *Education statistics annual abstract, 2021/22*. pp.47, 54, 55. The data in this edition exclude those of Tigray.

18 *Ibid.* p.46.

19 It should be noted that MoE, in spite of its intention, could not provide G9 and G10 Math textbooks for piloting to be used at 84 pilot secondary schools nationwide. The reasons are not clear but capacity limitation of the local printing companies is suspected to be the primary cause.

20 This figure is derived from the common fact that usually in Ethiopian schools, three students sit together at one desk.

approach should be introduced to CTE students in their normal courses. The exposure may also include the Rubric and its use. TELDA/MoE might consider including those topics in the revised CTE curriculum.

6.3 Changing Teaching Methods

6.3.1 Stop Writing Everything on the Blackboard

As observed in many lessons during the pilot monitoring and evaluation, teachers tend to write everything on the blackboard, without referring the students to the textbook. This characteristic is detrimental to students' achievement because, in so doing, they waste a considerable portion of lesson time in teacher's writing on the blackboard and students' copying it in their notebook.[21] As long as teachers continue this practice, positive effects of the new textbooks will be severely limited.

This practice seems rather hard to overcome. Needless to say, the prerequisite for its remedy is that a sufficient number of textbooks are distributed to the students. However, as some teachers at the MUST pilot schools have demonstrated, the "bad habit" is hard to die even when one textbook photocopy is available on each students' desk. Apparently, to overcome this characteristic requires teachers to do some practice in which they refrain from writing everything on the blackboard and, instead, refer the students to the textbook with clear instructions.

How to Cope with It?

One method effective to overcome this "bad habit" may be for teachers to prepare board writing plans. A board writing plan is a plan prepared by teacher for each lesson on what contents the teacher would write on the blackboard (and, at the same time, what contents he or she would not write). Board writing plans should be as concise and compact as possible to minimize the time students take to copy the blackboard. Only minimally essential words, expressions and figures should be written or drawn. Preparing good board writing plans requires some training. For that purpose, some training materials have been developed and stored in the "A-D-E-E Package."[22] Their application is strongly recommended in the induction training and follow-up training sessions to be organized by REBs.

6.3.2 Use the Time Given to Students More Effectively

Lesson observations have shown that about half math teachers now routinely give more than 10 minutes in one lesson for the students to solve exercise problems for themselves. This is a praiseworthy result in itself, but another issue has emerged: Teachers (and students) are not using the time given to students effectively enough. Some common observations:

- Teachers only check the notebooks of students who finished the work, and leave others unattended;
- Teachers do not give solution(s) to the whole class;
- Teachers spend too long time on one question;
- Teachers give too few questions to fast learners;
- Majority of students do not even try to solve the given problems for themselves, only waiting for the teacher or other students to show the answers to copy; teachers do not urge them to try to solve.

As long as such practices continue, the intended effect of the time given for students' self-activity should be curtailed. To give students at least 10 minutes for their independent problem-solving is the first step, and to utilize the time effectively for all the students to understand better is the second step ahead to go.

How to Cope with It?

It may not be so difficult for teachers to correct those practices. Since most teachers are not familiar with the "20-20 principle" to begin with, it seems natural that they do not know how to best utilize the given

[21] It is true that this practice was necessary when very few students had the textbook in the class. Many teachers routinely continue this practice, however, even when more textbooks are available for the students.

[22] See the six powerpoint files contained in the folder named "4-2. [Induction] Let's prepare ADEE lesson using Unit Plans!"

time to facilitate every student's understanding. The five common poor practices described above may be easily overcome once teachers get clearly aware of the problems and intentionally correct such behavior in daily lessons. Of course, they first need to realize the problems. Training may be the only and best way to make the teachers aware of them. Once they know the problems, they can change their practices with the help of specific hints about teaching techniques, which the training can also deliver.

The Rubric can guide the teachers in regard to this aspect, too. Three criteria under the heading of "Quality of self-problem-solving time" (No. 7, 8 and 9) deal with the problems. By reflecting on their lessons regularly using the Rubric, teachers can be constantly reminded of the problems and guided to improved lessons where students' time will be used more effectively.

The last problem mentioned above about the students who just wait for the answers to be given will require a special treatment by the teacher. To urge such students to try to solve the problems by themselves and, further, to make it a habit of the students, teachers need to always handle an example and its matching exercise as a pair and urge the students to solve the exercise applying the method just explained in the example. Teachers should repeat this simple practice consistently from the first lesson of the school year until the students do it as a habit. This point is an important element of the A-D-E-E structured teaching method and should be explained and trained to teachers in the induction training and its follow-up.

6.4 Institutionalizing the A-D-E-E Structure

MUST has proved, though in a limited way, that the new textbooks can improve students' performance when combined with the new teaching method of A-D-E-E structure. If this evaluation holds even after the full implementation of the new textbooks in 2023/24, MoE may consider institutionalizing the A-D-E-E structure in Ethiopia.

The first step necessary for its institutionalization may be to declare in the Curriculum Framework that the A-D-E-E structure should be adopted, in principle and where appropriate, to all subjects of all grades. In view of secondary school students' generally low achievement in mathematics, it would be crucially important to adopt the structure to primary school math textbooks. Since the new primary textbooks have just been published, the adoption of the A-D-E-E structure to the primary textbooks is necessarily a long-term task but, if implemented, will have a profound impact on students' achievement both at primary and secondary levels.

6.5 Making Textbooks Slimmer[23]

The new mathematics textbooks for G9 to G12 are thick. They are thicker than the previous textbooks. Thick textbooks have three shortcomings:

1. Students do not take them to class, because they are heavy to carry.
2. Teachers cannot finish the contents within a year.
3. Thick textbooks cost MoE more in printing and distribution.

Students generally do not like to carry bulky and heavy textbooks to school every day. Since students do not have the textbook in the lesson, teachers are obliged to write everything to teach on the blackboard. Students then diligently copy the blackboard. This way, a considerable part of lesson time is lost in writing and copying. This will explain, at least partly, the low math achievement of the Ethiopian students.

One reason for thick textbooks is that, for mathematics, 156 lesson periods are assumed to be taught a year (4 periods a week times 39 weeks).[24] The syllabi are all based on this assumption. In reality, however, this number is far more than teachers generally can secure for a year. Judging from the information collected by the JICA Expert Team for MUST from teacher and school interviews, 120 is a more likely figure. Aa a matter of fact, even with the current textbooks, most teachers cannot finish all the contents by the end of the school year and are forced to teach some contents cursorily. If the school time is based on the realistic assumption of 120 periods a year, the syllabi should be thoroughly revised accordingly, and

[23] This section is an extract from Section 8.3 Potential Benefits of Slimmer Textbooks of *Report on the Pilot Monitoring and Evaluation*.

[24] Ministry of Education. (2020, December). *General education curriculum framework*. p.44, pp.48-51.

textbook contents should be significantly reduced. Teachers can finish a compact textbook within allocated lesson periods without much haste. This will in turn improve students' understanding.

Thick textbooks will cost MoE a lot more than slim ones in printing and distribution. If thick textbooks actually hamper students' better learning, it means that MoE is spending extra budget to prevent the students from understanding mathematics better. This paradox must be avoided.

The potential benefits of slim textbooks were verified in an unintended experiment. After piloting of G9 and G10 new textbooks started in September 2022, it so happened that the JICA Expert Team for MUST distributed photocopies of part of the new textbooks to the students of the three pilot schools. This turned out to be an unintended experiment on slim textbooks. In lessons observed, students seemed to love the photocopy, which was only a few millimeters thick, and dutifully displayed it on their desk during the lesson. At the beginning, almost all photocopies (20 to 25 per section) were thus brought to the lesson and referred to without teacher's instruction. This testifies that slim textbooks will have a better chance to be brought to school and used in the lesson by students.

How to Cope with It?

Three approaches are necessary to make textbooks slim.

First, the ***curriculum framework*** needs to be revised to reduce the total number of annual lesson periods (156) to a more realistic one (around 120). The JICA Expert Team for MUST has repeatedly pointed out this necessity since they first reviewed the curriculum documents in early 2021.

Second, the ***syllabi*** should be thoroughly revised. To make the contents fit into 120 or so lesson periods, the current contents need to be reviewed.

Third, the ***textbooks*** themselves can reduce page numbers by following measures:

1. Layout

By streamlining the layout of pages, we can further minimize unnecessary space often found in the new textbooks.

2. Graphs, Figures, Tables

By reducing the size of graphs, figures and tables to the minimally necessary size, we can save space.

3. Examples

In a number of lessons, more than three examples are given for one lesson. Practically speaking, it would be impossible for teachers to explain more than three examples just in one lesson. To delete such "excessive" examples, however, we first need to revise the syllabus because those examples all correspond to some specifications or other given in the syllabus; no examples are "redundant" in that sense. Nonetheless, if this adjustment is completely done, it will very effectively reduce the page numbers of the new textbooks.

Potential benefits of slimmer textbooks are enormous. It would be highly recommended for MoE to spend significantly more time on deliberation of the Curriculum Framework and syllabi and on development of textbooks when they are to be revised next time. It should not be done in a hasty manner if slimmer textbooks should be materialized.

For teachers, MUST would strongly suggest utilizing the **List of Contents** as a partial and tentative remedy to overcome the problems of the thick textbooks. Following this list, teachers can easily identify which lessons (or topics) are minimally required for students to master. By focusing their time on those 120 "essential" lessons, teachers may be able to complete the textbook within a year and, consequently, improve students' understanding of the topics. MUST distributed this List of Contents to all REBs in July 2023 and hopes that teachers throughout Ethiopia will refer to it when making their annual lesson plan.

APPENDIX

Appendix 1 Project Design Matrix (Original)

Project Design Matrix (Amended, Ver. 1.0, Dated on Oct. 19, 2018)

Project Title: Mathematical Understanding for Science and Technology (MUST)
Implementation Agency: Mathematics and Science Improvement Center (MSIC) and other institutions
Target Group: 1. Grade 1-8 primary school students in model schools: *** students
2. Grade 1-8 primary school teachers in model schools: ***teachers
3. Grade 1-8 primary school students in evaluation schools: *** students
4. Grade 1-8 primary school teachers in evaluation schools: ***teachers
Period of Project: March 2019 - August 2023
Project Site: ***

(Ver. 1.0, Dated on Oct. 19, 2018)

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement
Super Goal Quality of basic education is improved.	To be decided			
Overall Goal Students' learning outcomes of satellite schools in model-school clusters are improved.	Student test scores	Student test will be administered.		
Project Purpose A scale-up model for improving students' learning outcomes in mathematics is developed.	1. Developed model 2. Student test scores at evaluation schools	Student test will be administered by the Project.	Cluster system is in function (budget necessary for maintaining cluster activities is secured).	
Outputs				
1 Reasons for lower academic achievement of primary school students in mathematics are analyzed.	Identified reasons	Analysis report		
2 Lesson support materials for students and teachers are developed in grade 1-8 mathematics.	1. Developed Lesson support materials for students and teachers 2. Quality of materials	Project report Questionnaire		

3	Good practices in implementing lesson support materials for students and teachers are identified in each model school.	1. Percentage of teachers and students who are satisfied with the materials 2. Compiled good teaching practices	Questionnaire Project report		
4	A scale-up model is evaluated in evaluation schools.	1. Percentage of teachers who use the materials. 2. Percentage of teachers and students who are satisfied with the materials.	Questionnaire		
5	Recommendations for revising curriculum and textbooks are compiled.	Recommendations	Recommendation report		

Activities	Inputs	
	The Japanese Side	**The Ethiopian Side**
1 Reasons for lower academic achievement of primary school students in mathematics are analyzed.	- Dispatch of Japanese experts (Team members are subject to the availabilities of human resources. The following members are possible members.) *Team leader/Math and Science Education *Coordinator/ Planning and Management *Math education adviser	- Staff assignment according to implementation structure - Operational cost for model schools - Office space at MoE - Running cost of the office - Any allowances, accommodation, and travel costs on federal and regional officials, and teachers including
1 Conduct curriculum and textbooks analysis to find out any necessary improvements for quality learning.		
2 Conduct baseline survey to measure the status of students' learning in grade 1-8.		
3 Analyze the results of base line survey.		
4 Conduct wrong-answer analysis and other relevant analysis of the test results.		
5 Conduct lesson observations.		
6 Compile findings from various analysis and observations.		
2 Lesson support materials for students and teachers are developed in grade 1-8 mathematics.		
1 Draw suggestions from the analysis on lesson support materials for students and teachers.		
2 Draft lesson support materials for students and teachers.		
3 Conduct workshops for sharing experiences on writing Lesson support materials for students and teachers.		
4 Identify some of Contests Development Schools, by which draft lesson support materials for students and teachers are tried out.		
5 Translate lesson support materials for students and teachers for selected Model Schools.		
6 Print lesson support materials for students and teachers.		
3 Good practices in implementing lesson support materials for students and teachers are identified in each model school.		
1 Identify model schools.		
2 Conduct training for teachers on how to use lesson support materials for students and teachers.		
3 Conduct training for school directors on how to manage the implementation of the materials.		
4 Conduct training for officers in regional and local officers on how to monitor progress in model schools.		
5 Conduct training for TEC instructors on how to support teachers in model schools.		

	6	Distribute lesson support materials for students and teachers.	*Mathematics Curriculum adviser *Monitoring and Assessment adviser - Provision of necessary equipment - Project vehicle(s) - Short term training in Japan or other countries 【Outside of the project】 - Volunteers	CTE when the Project conducts any activities
	7	Tryout draft lesson support materials for students and teachers		
	8	Validate lesson support materials for students and teachers		
	9	Promote peer-learning opportunities, by using the existing CPD framework in model schools.		
	10	Conduct stakeholders meeting on the progress of the implementation of the materials.		
	11	Monitor and support the progress of the implementation of the materials.		
	12	Conduct experience sharing workshops on good practices in implementing the materials.		
	13	Share experiences with satellite schools.		
4	**A scale-up model is evaluated in evaluation schools.**			
	1	Identify some of good teaching practices which can scale nationwide.		
	2	Develop a model for scale.		
	3	Design a framework for the evaluation of lesson support materials for students and teachers.		
	4	Try out lesson support materials for students and teachers in evaluation schools.		
	5	Evaluate the impact of lesson support materials for students and teachers.		
5	**Recommendations for revising curriculum and textbooks are compiled.**			
	1	Draw suggestions from the analysis on curriculum and textbooks.		
	2	Incorporate recommendations to the first draft of lesson support materials for students and teachers.		
	3	Implement lesson support materials for students and teachers.		
	4	Draw lessons learned on the usage of the lesson support materials from the implementation.		
	5	Compile lessons learned.		

Appendix 2 Project Design Matrix (Revised, Ver 4)

Project Design Matrix (Amended) Annex 3

Project Title: Mathematical Understanding for Science and Technology (MUST) Version: 4
Implementing Agency: Curriculum Development and Implementation Directorate (CDID), Mathematics and Science Improvement Center (MSIC) Dated: September 26th, 2022
and other concerned directorates
Project Duration: March 2019~August 2023
Target Group:
Direct Beneficiaries
1. Grades 9-12 students in all regions: 6,993,656 students
2. Grades 9-12 mathematics teachers in all regions: 14,640 teachers
3. CDID, MSIC Mathematics Experts
4. Regional Education Bureaus Mathematics Experts of all regions
Indirect beneficiaries:
1. Grade 1-8 students in all regions 24,620,963 students
2. Grade 1-8 Mathematics teachers in all regions (46,244 teachers)

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Super Goal The learning performance in mathematics is improved.	Results of the national examination on mathematics are improved compared to those of 2020.	1. MoE and/or REB report 2. NLA Report by NEAEA			
Overall Goal Educational activities based on the new mathematics curriculum are promoted.	1. New Grades 9-12 math textbooks are distributed and used in more than 75% of the secondary schools after full implementation of the new curriculum. 2. Strategies for learning improvement for Grades 9-12 in Ethiopia are developed. 3. New Grades 1-8 math textbooks have been produced by REB based on new syllabus in all regions after full implementation of the new curriculum.	1. MoE monitoring report 2. REB monitoring report 3. REB monitoring report	All secondary mathematics teachers are trained based on strategies for learning improvement for Grades 9-12 in Ethiopia		
Project Purpose Educational activities based on the new mathematics curriculum are introduced.	1. New Grades 9-12 math textbooks are authorized by MoE. 2. The drafted learning improvement strategy for Ethiopia is presented to regional stakeholders. 3. 60% of participants of the technical WS have applied the knowledge learned during the WS in order to produce Grades1-8 textbooks.	1. MoE document 2. MoE monitoring report 3. Project report and/or MoE document	Teaching and learning materials based on the new math curriculum are accessible for teachers and learners. The MoE works to disseminate the draft learning improvement strategy for Ethiopia		

Outputs						
1	Quality of the mathematics curriculum documents (flow charts, MLCs, and syllabi) is assured.	1. Three curriculum documents are approved by MoE.	1. MoE and/or project document			
2	Technical recommendations, based on the situational analysis of classroom practices, are incorporated to Grades 9-12 textbook editing strategies and M&E.	1. Five directions (viewpoints) for draft textbook revision are approved by MoE.	1. Project report and/or document			
3	The capacity in developing Grades 1-8 mathematics teaching materials are improved through technical WS.	1. 60% of participants of the technical WS have learned new knowledge for textbook development to apply in developing Grades 1-8 mathmetics textbooks.	1. Project report			
4	The quality of Grades 9-12 textbook contents is improved.	1. Improvements are observed in the final version of textbooks compared with the Draft 0 textbooks. 1-1. 100% of units/sub-units are corrected and improved in terms of layout, math expressions, figures, graphs, etc. 1-2. 100% of units/sub-units are "unitized" in the lesson structure. 1-3. Evaluation items (basic problems) are included in Exercises.	1. Project report and/or MoE report			
5	Strategies for improving the utilization of Grades 9-12 textbooks are proposed based on monitoring and evaluation.	1. Students are provided with over 10 minutes to solve exercise in one lesson when using the new textbooks. 2. Results of Math achievement test/Unit test at MUST pilot schools with the new textbooks and MUST intervention is better than non-pilot schools with the previous textbooks. 3. Draft learning improvement strategies for Ethiopia is proposed.	1. Project report 2. Project report 3. Project report			

Activities	Inputs		Important Assumption
	The Japanese Side	The Ethiopian Side	
1 Quality of the mathematics curriculum documents (flow charts, MLCs, and syllabi) is assured.	- Dispatch of Japanese experts (Team members are subject to the availabilities of human resources. The following members are possible members.) * Team leader/Math and Science Education * Coordinator/Planning and Management * Mathematics Curriculum/Textbook advisers * Monitoring and Assessment adviser ** Math education adviser (longterm) - Provision of equipment necessary to implement activities in the PDM - Project vehicle(s) - Short term training in Japan or other countries(may be subsequent to online training depending on the Covid-19 situation) 【Outside of the project】 - Volunteers	- Staff assignment according to implementation structure - Office space at CDID - Running cost of the office - Any allowances, accommodation, and travel costs on federal and regional officials, and teachers including CTE when the Project conducts any activities	The new math textbook dissemination plan will be conducted as planned.
1 Make a technical support plan.			
2 Conduct (online) technical support of the curriculum materials (flow charts, MLC, and syllabi) for Grades 1-12.			
3 Revise and finalize the curriculum materials.			
4 Conduct a validation workshop for the curriculum materials			
2 Technical recommendations, based on the situational analysis of classroom practices, are incorporated to Grades 9-12 textbook editing strategies and M&E.			
1 Conduct a situational survey.			
2 Make concrete recommendations during the development process to improve Grades 9-12 textbook editing.			
3 The capacity in developing Grades 1-8 mathematics teaching materials are improved through technical WS.			
1 Create a technical support plan for REB textbook writers.			
2 Develop Grades 1,4,7 teaching and learning material samples for the main purpose of capacity development for Grades 1-8 REB textbook writers.			
3 Conduct workshops for REB textbook writers to develop the capacity to write textbooks.			
4 The quality of Grades 9-12 textbook contents is improved.			**Pre-conditions**
1 Conduct workshops for textbook developers to improve draft Grades 9-12 textbooks and teachers guide.			
2 Provide further technical suport to improve draft Grades 9-12 textbooks and teachers guide.			
5 Strategies for improving the learning of students by utilizing Grades 9-12 textbooks are proposed based on monitoring and evaluation.			
1 Select MUST pilot schools and MUST non-pilot schools to verify the learning improvement mechanism.			
2 Conduct induction training to MoE pilot schools in CDID/MoE-organized workshops.			
3 Conduct pre-pilot training for Grades 9-10 math teachers at MUST pilot schools.			
4 Provide special support to Grades 9-10 math model teachers at MUST pilot schools.			
5 Conduct achievement tests and unit tests at MUST pilot schools and non-pilot schools.			
6 Conduct lesson observation at MUST pilot schools and non-pilot schools.			
7 Compile the results of MUST M&E activities.			
8 Conduct a nation-wide workshop to share the MUST/MoE pilot experiences among stakeholders.			
9 Collect data on Grades 9-12 textbook usage at the classroom level through M&E .			
10 Make strategies to improve the learning achievement of students using Grades 9-12 textbooks at the classroom level.			

Appendix 3 Plan of Operation (Period 2)

Appendix 4

Tentative Plan of Operation

Version 2.0

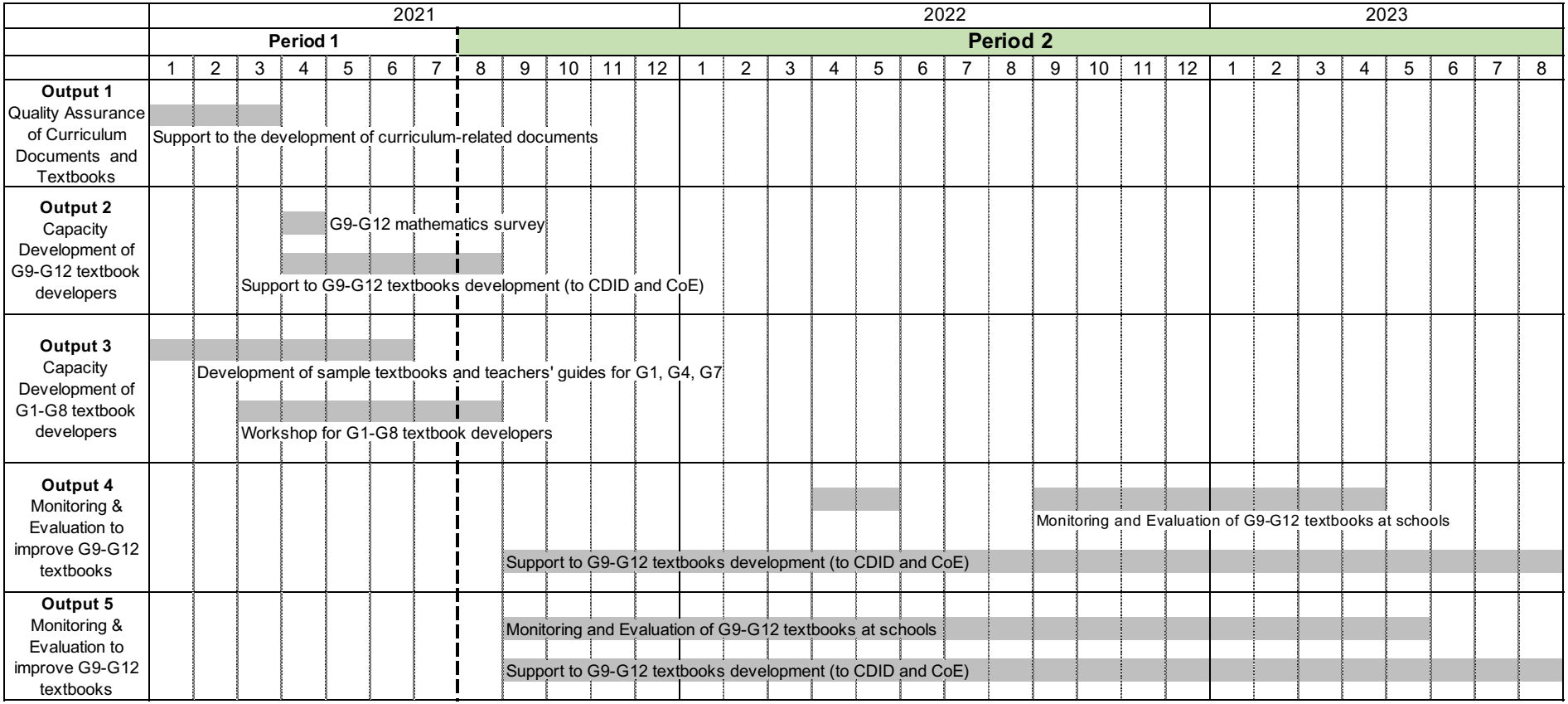
Dated 16 December 2020

Project Title: Mathematical Understanding for Science and Technology (MUST)

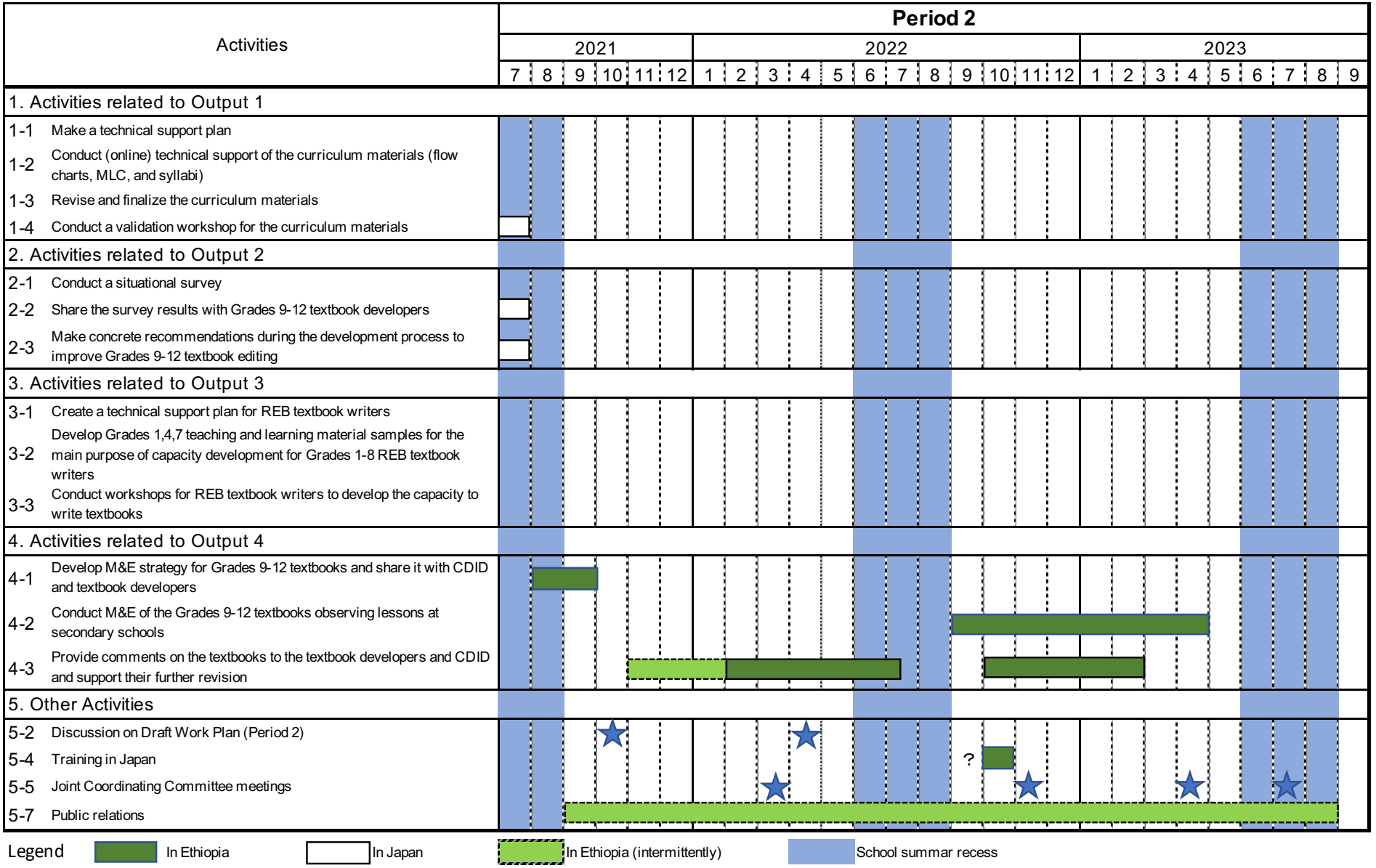
Inputs	Year	2019				2020				2021				2022				2023				Remarks	Monitoring: Issue	Monitoring: Solution
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV			
Expert (subjective to the availabilities)																								
Team Leader / Math and Science Education	Plan																							
	Actual																							
Mathematics Curriculum/Textbook Advisers	Plan																							
	Actual																							
Mathematics Education Adviser	Plan																							
	Actual																							
Equipment																								
To be confirmed	Plan																							
	Actual																							
	Plan																							
	Actual																							
Training in Japan																								
Mathematics Education	Plan																							
	Actual																							
In-country/Third country Training																								
	Plan																							
	Actual																							

Activities / Sub-Activities	Year	2019				2020				2021				2022				2023				Responsible Organization: Japan	Responsible Organization: GO●●	Achievements	Issue & Countermeasures
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV				
Output 1: Quality of the mathematics curriculum documents (flow charts, MLCs, and syllabi) are assured.																									
1.1 Make a technical support plan.	Plan																								
	Actual																								
1.2 Conduct technical support of the curriculum materials (flow charts, MLC, and syllabi) for G1-12.	Plan																								
	Actual																								
1.3 Revise and finalize the curriculum materials.	Plan																								
	Actual																								
1.4 Conduct a validation workshop for the curriculum materials	Plan																								
	Actual																								
Output 2: Technical recommendations, based on the situational analysis of classroom practices, are incorporated to G9-12 textbook editing strategies and M&E																									
2.1 Conduct a situational survey.	Plan																								
	Actual																								
2.2 Make concrete recommendations during the development process to improve Grades 9-12 textbook editing.	Plan																								
	Actual																								
Output 3:The capacity in developing Grades 1-8 mathematics teaching materials are improved through technical WS.																									
3.1 Create a technical support plan for REB textbook writers.	Plan																								
	Actual																								
3.2 Develop Grades 1,4,7 teaching and learning material samples for the main purpose of capacity development for Grades 1-8 REB textbook	Plan																								
	Actual																								
3.3 Conduct workshops for capacity development in textbook writing.	Plan																								
	Actual																								
3.4 Create M&E plans for designated regional monitored schools.	Plan																								
	Actual																								
3.5 Conduct M&E on the new curriculum induction process (Textbook development and M&E) at the regional level	Plan																								
	Actual																								
Output 4: The quality of Grades 9-12 textbook contents are improved.																									
4.1 Conduct M&E.	Plan																								
	Actual																								
4.2 Provide technical support to G9-12 textbook wrtiers.	Plan																								
	Actual																								
4.3 Revise G9-12 textbooks.	Plan																								
	Actual																								
Output 5: Strategies for improving the utilization of Grades9-12 textbooks are proposed based on monitoring and evaluation.																									
5.1 Collect data on G9-12 textbook usage at the classroom level through M&E.	Plan																								
	Actual																								
5.2 Make strategies to improve the utilization of G9-12 textbooks at the classroom level.	Plan																								
	Actual																								
Duration / Phasing	Plan	Preparation stage				First academic year				Second academic year				Third academic year				Fourth academic year							
	Actual																								

Appendix 4 Work Flow (Period 2)



Appendix 5 Work Plan (Period 2)



Appendix 6 Assignment Chart (Period 2)

Project for Mathematical Understading for Science and Technology (MUST)

Period 2 (August 2021~August 2023)

As of May 31, 2023

	Assignment	Name	Affiliation	Period 2	Man/Month	
				2021: 8 9 10 11 12 / 2022: 1 2 3 4 5 6 7 8 9 10 11 12 / 2023: 1 2 3 4 5 6 7 8 9	Ethio	Japan
In Ethiopia	1. Team Leader/ Mathematics Education	Norimichi Toyomane	IDCJ	(50) (37) (45) (52) (43) (31) (53) (24)	11.17	
	2. Deputy Team Leader/ Mathematics Education	Nahoko Chiku	JDS	(48) (27) (45) (39) (26) (15) (15) (10) (15) (10)	8.33	
	3. Development of Mathematics Materials 1	Shimboku Miyakawa	IDCJ (Miyakawa)	(36) (23)	1.97	
	4. Development of Mathematics Materials 2	Kan Motoyama	VSOC	(34) (25) (31)	3.00	
	5. Development of Mathematics Materials 3	Etsutaro Tanaka	VSOC	(50) (48) (46)	4.80	
	6. Development of Mathematics Materials 4	Kazumi Katsumata	KRC	(33) (63) (31)	4.23	
	7. Development of Mathematics Materials 5	Ken Furukawa	KRC	(24) (29)	1.77	
	8. Development of Mathematics Materials 6	Yuta Yoneda	KRC		0.00	
	9. Mathematics Curriculum	Izumi Nishitani	IDCJ (Individual)		0.00	
	10. Materials Editing	Masaomi Hirose	IDCJ (Individual)		0.00	
	11. Monitoring 1／Project Administration 1	Michiru Yabuta	IDCJ	(27)	0.90	
	12. Monitoring 2/ Development of Mathematics Materials 7	Akira Sakayori	IDCJ	(39) (22)	2.03	
	13. Monitoring 3／Project Administration 2	Shunsuke Nishioka	KRC		0.00	
	14. Monitoring 4／Project Administration 3	Masato Kamoda	IDCJ	(24) (32) (31) (21)	3.60	
				Subtotal	41.80	

In Japan

1.	Team Leader/ Mathematics Education	Norimichi Toyomane	IDCJ	(10)	0.50
2.	Deputy Team Leader/ Mathematics Education	Nahoko Chiku	JDS	(6) (10)	0.80
3.	Development of Mathematics Materials 1	Shimboku Miyakawa	IDCJ (Miyakawa)	(8) (4) (4) (2)	0.90
4.	Development of Mathematics Materials 2	Kan Motoyama	VSOC	(8) (2) (2) (6)	0.90
5.	Development of Mathematics Materials 3	Etsutaro Tanaka	VSOC	(8) (2) (2)	0.60
6.	Development of Mathematics Materials 4	Kazumi Katsumata	KRC	(8) (50)	2.90
7.	Development of Mathematics Materials 5	Ken Furukawa	KRC	(8) (14)	1.10
8.	Development of Mathematics Materials 6	Yuta Yoneda	KRC	(33)	1.65
9.	Mathematics Curriculum	Izumi Nishitani	IDCJ (Individual)	(8) (8)	0.80
10.	Materials Editing	Masaomi Hirose	IDCJ (Individual)		0.00
11.	Monitoring 1／Project Administration 1	Michiru Yabuta	IDCJ	(8) (16)	1.20
12.	Monitoring 2/ Development of Mathematics Materials 7	Akira Sakayori	IDCJ	(7)	0.35
13.	Monitoring 3／Project Administration 2	Shunsuke Nishioka	KRC	(27)	1.35
14.	Monitoring 4／Project Administration 3	Masato Kamoda	IDCJ	(5) (2)	0.35
				Subtotal	13.40

Reporting	Report（△）	△ Monitoring Sheet No.4	△ Monitoring Sheet No.5 △ Work Plan (Period 2) △ Progress Report △ Monitoring Sheet No.6 △ Monitoring Sheet No.7 △ Project Completion Report
	Technical Output（△）	△ Revised G9~G12 mathematics textbooks	
	Joint Coordinating Committee（JCC）	▲	▲ ▲ ▲

Total	41.80	13.40
	55.20	

Legend: Work in Ethiopia; Work in Japan; Busy period and summar recess for schools

Appendix 7 Current Textbook on "Quadratic Equations" (G9 Unit 2)

3 Solve each of the following equations.

a $|5-x| = |3x-7|$ **b** $|3x-2| = |3x-7|$

c $|5-4x| = |7+3x|$ **d** $|3x+4|-|x+7| = 0$

e $|7-(x+3)|+|3x-3| = 0$

4 Solve each of the following equations.

a $|x-3|+|x-3| = 9$ **b** $|3x+2|-|x-3| = 5$

c $|-(2x-3)|+|x| = 12$ **d** $|4x-2| = 8+|x-3|$

e $|5x-(1-2x)|-|3-2x| = 8$ **f** $|12-(x+7)|+|x-3| = 3$

Hint: Here, for $|x+a|+|x+b| = c$, notice that $|x+a|$ takes either $x+a$ or $-(x+a)$ and also $|x+b|$ takes either $x+b$ or $-(x+b)$, depending on whether they are greater than 0 or less than 0. Therefore, you need to consider four cases to solve such problems!

5 Verify each of the following.

a $|y-x| \le |x|+|y|$ when $x = -2$ and $y = 3$.

b $\sqrt{(3x-7)^2} = |3x-7|$, when $x = 5$.

2.4 QUADRATIC EQUATIONS

Recall that for real numbers a and b, any equation that can be reduced to the form

$ax + b = 0$, where $a \neq 0$ is called a linear equation.

Following the same analogy, for real numbers a, b and c, any equation that can be reduced to the form

$ax^2 + bx + c = 0$, where $a \neq 0$ is called a quadratic equation.

$x^2 + 3x - 2 = 0$, $2x^2 - 5x = 3$, $3x^2 - 6x = 0$, $(x+3)(x+2) = 7$ etc, are examples of quadratic equations.

In this section, you will study solving quadratic equations. You will discuss three major approaches to solve quadratic equations, namely, the method of factorization, the method of completing the square, and the general formula. Before you proceed to solve quadratic equations, you will first discuss the concept of factorization.

Expressions

Expressions are combinations of various terms that are represented as a product of variables or numbers and variables.

Example 1 $x^2 + 2x$, $2x^2 + 4x + 2$, $(x+1)x^2 + 6x$, etc. are expressions.

x^2 and $2x$ are the terms in $x^2 + 2x$ and $2x^2$, $4x$, and 2 are the terms in $2x^2 + 4x + 2$.

Factorizing trinomials

You saw how to factorize expressions that have common factors. You also saw factorizing the difference of two squares. Now you will see how to factorize a trinomial $ax^2 + bx + c$ by grouping terms, if you are able to find two numbers p and q such that $p + q = b$ and $pq = ac$.

Example 7 Factorize $x^2 + 5x + 6$.

Solution: Two numbers whose sum is 5 and product 6 are 2 and 3.

So, in the expression, we write $2x + 3x$ instead of $5x$:

$x^2 + 5x + 6 = x^2 + (2x + 3x) + 6$ because $2x + 3x = 5x$.

$= (x^2 + 2x) + (3x + 6)$ (*grouping into two parts*)

$= x(x+2) + 3(x+2)\ldots$ (*factorizing each part*)

$= (x+2)(x+3)$ because $(x+2)$ is a common factor.

Example 8 Factorize $x^2 + 4x + 4$.

Solution: Two numbers whose sum is 4 and product 4 are 2 and 2. So take $2x + 2x$ instead of $4x$:

$x^2 + 4x + 4 = x^2 + (2x + 2x) + 4$ because $2x + 2x = 4x$

$= (x^2 + 2x) + (2x + 4)$....(*grouping*)

$= x(x+2) + 2(x+2)$.....(*take out the common factor for each group*)

$= (x+2)(x+2) = (x+2)^2$.

Such expressions are called perfect squares.

Example 9 Factorize $3x^2 - 14x - 5$.

Solution: Do you have numbers whose sum is -14 and whose product is $3\times-5 = -15$?

$-15 + 1 = -14$ and $-15 \times 1 = -15$. This means you can use -15 and 1 for grouping, giving

$3x^2 - 14x - 5 = 3x^2 - 15x + x - 5$

$= (3x^2 - 15x) + (x - 5)$

$= 3x(x-5) + 1(x-5)$

$= (3x+1)(x-5)$

Factorizing expressions

ACTIVITY 2.8

1 Multiply each of the following.

a $x(x+9)$ **b** $(x+3)(x-3)$ **c** $(x+2)(x+3)$

2 How would it be possible to go back from products to factors? Factorize each of the following.

a $x^2 - 9$ **b** $x^2 + 9x$ **c** $x^2 + 5x + 6$

Factorizing an expression is expressing it as a product of its simplest factors.

Example 2 Factorize $2x^2 - 9x$.

Solution: The two terms in this expression, $2x^2$ and $-9x$, have x as a common factor. Hence $2x^2 - 9x$ can be factorized as $x(2x-9)$.

So $2x^2 - 9x = x(2x-9)$.

Example 3 Factorize $4x^2 + 12x$.

Solution: $4x^2 + 12x = (4x)x + 3(4x) = (4x)(x+3)$

Example 4 Factorize $(2x-1)(3x) + 2(2x-1)$.

Solution: $(2x-1)(3x) + 2(2x-1) = (2x-1)(3x+2)$ since $(2x-1)$ is a common factor.

Factorizing the difference of two squares

If we multiply $(x+2)$ and $(x-2)$, we see that $(x+2)(x-2) = x^2 - 4 = x^2 - 2^2$.

ACTIVITY 2.9

1 What is $75^2 - 25^2$? How would you compute this?

2 What is $200^2 - 100^2$?

In general,

$x^2 - a^2 = (x-a)(x+a)$.

Example 5 Factorize $x^2 - 9$.

Solution: $x^2 - 9 = x^2 - 3^2 = (x-3)(x+3)$

Example 6 Factorize $4x^2 - 16$.

Solution: $4x^2 - 16 = (2x)^2 - 16 = (2x)^2 - 4^2 = (2x-4)(2x+4)$

So $3x^2 - 14x - 5 = (3x+1)(x-5)$.

ACTIVITY 2.10

Factorize each of the following.

a $2x^2 + 10x + 12$ **b** $2x^2 - x - 21$ **c** $5x^2 + 14x + 9$

Solving quadratic equations using the method of factorization

Let $ax^2 + bx + c = 0$ be a quadratic equation and let the quadratic polynomial $ax^2 + bx + c$ be expressible as a product of two linear factors, say $(dx + e)$ and $(fx + g)$ where d, e, f, g are real numbers such that $d \neq 0$ and $f \neq 0$.

Then $ax^2 + bx + c = 0$ becomes

$(dx + e)(fx + g) = 0$

So, $dx + e = 0$ or $fx + g = 0$ which gives $x = \frac{-e}{d}$ or $x = \frac{-g}{f}$.

Therefore $x = \frac{-e}{d}$ and $x = \frac{-g}{f}$ are possible roots of the quadratic equation $ax^2 + bx + c = 0$.

For example, the equation $x^2 - 5x + 6 = 0$ can be expressed as:

$(x-2)(x-3) = 0$

$x - 2 = 0$ or $x - 3 = 0$

$x = 2$ or $x = 3$

Therefore the solutions of the equation $x^2 - 5x + 6 = 0$ are $x = 2$ and $x = 3$.

In order to solve a quadratic equation by factorization, go through the following steps:

i Clear all fractions and square roots (if any).

ii Write the equation in the form $p(x) = 0$.

iii Factorize the left hand side into a product of two linear factors.

iv Use the *zero-product rule* to solve the resulting equation.

Zero-product rule: If a and b are two numbers or expressions and if $ab = 0$, then either $a = 0$ or $b = 0$ or both $a = 0$ and $b = 0$.

Example 10 Solve each of the following quadratic equations.

a $4x^2-16=0$ **b** $x^2+9x+8=0$ **c** $2x^2-6x+7=3$

Solution:

a $4x^2-16=0$ is the same as $(2x)^2-4^2=0$

$(2x-4)(2x+4)=0$

$(2x-4)=0$ or $(2x+4)=0$

Therefore, $x=2$ or $x=-2$.

b $x^2+9x+8=0$

$x^2+x+8x+8=0$

$(x^2+x)+(8x+8)=0$

$x(x+1)+8(x+1)=0$

$(x+1)(x+8)=0$

$(x+1)=0$ or $(x+8)=0$

Therefore, $x=-1$ or $x=-8$.

c $2x^2-6x+7=3$ is the same as $2x^2-6x+4=0$

$2x^2-6x+4=0$ can be expressed as

$2x^2-2x-4x+4=0$; (-2 and -4 have sum $=-6$ and product $=8$).

$(2x^2-2x)-(4x-4)=0$

$2x(x-1)-4(x-1)=0$

$(2x-4)(x-1)=0$

$(2x-4)=0$ or $(x-1)=0$

Therefore, $x=2$ or $x=1$.

Exercise 2.4

1 Solve each of the following equations.

a $(x-3)(x+4)=0$ **b** $2x^2-6x=0$ **c** $x^2-3x+4=4$

d $2x^2-8=0$ **e** $5x^2=6x$ **f** $x^2-2x-12=7x-12$

g $-x^2-4=0$ **h** $2x^2+8=0$

2 Solve each of the following equations.

a $x^2-6x+5=0$ **b** $3x^2-2x-5=0$ **c** $x^2+7x=18$

d $-x^2=8x-9$ **e** $5y^2-6y+1=0$ **f** $3z^2+10z=8$

3 Find the solution set of each of the following.

a $2x^2+\frac{3}{2}x+\frac{1}{4}=0$ **b** $x^2=-2.5x+\frac{25}{16}$

c $-(6+2x^2)+8x=0$

Solving quadratic equations by completing the square

Group Work 2.5

Considering $2x^2+5x-4=0$, form a group and do the following.

1 Divide each coefficient by 2.

2 Shift the constant term to the right hand side (RHS).

3 Add the square of half of the middle term to both sides.

4 Do we have any perfect square? Why or why not?

5 Do you observe that $\left(x+\frac{5}{4}\right)^2=\frac{57}{16}$?

6 Discuss the solution.

In many cases, it is not convenient to solve a quadratic equation by factorization method. For example, consider the equation $x^2+8x+4=0$. If you want to factorize the left hand side of the equation, i.e., the polynomial x^2+8x+4, using the method of splitting the middle term, you need to find two integers whose sum is 8 and product is 4. But this is not possible. In such cases, an alternative method as demonstrated below is convenient.

$x^2+8x+4=0$

$x^2+8x=-4$

$x^2+8x+(4)^2=-4+(4)^2$ $\left(\text{Adding }\left(\frac{1}{2}\text{Coefficient of }x\right)^2\text{ on both sides}\right)$

$(x+4)^2=-4+16=12$ $(x^2+8x+16=(x+4)^2)$

$x+4=\pm\sqrt{12}$ (Taking square root of both sides)

Therefore $x=-4+\sqrt{12}$ and $x=-4-\sqrt{12}$ are the required solutions.

This method is known as the method of completing the square.

In general, go through the following steps in order to solve a quadratic equation by the method of completing the square:

i Write the given quadratic equation in the standard form.

ii Make the coefficient of x^2 unity, if it is not.

iii Shift the constant term to R.H.S.(Right Hand Side)

iv Add $\left(\frac{1}{2}\text{coefficient of }x\right)^2$ on both sides.

v Express L.H.S.(Left Hand Side) as the perfect square of a suitable binomial expression and simplify the R.H.S.

vi Take square root of both the sides.

vii Obtain the values of x by shifting the constant term from L.H.S. to R.H.S.

Note: The number we need to add (or subtract) to construct a perfect square is determined by using the following product formulas:

$x^2+2ax+a^2=(x+a)^2$

$x^2-2ax+a^2=(x-a)^2$

Note that the last term, a^2, on the left side of the formulae is the square of one-half of the coefficient of x and the coefficient of x^2 is +1. So, we should add (or subtract) a suitable number to get this form.

Example 11 Solve $x^2+5x-3=0$.

Solution: Note that $\left(\frac{5}{2}\right)^2=\frac{25}{4}$.

Hence, we add this number to get a perfect square.

$x^2+5x-3=0$

$x^2+5x=3$

$x^2+5x+\frac{25}{4}=3+\frac{25}{4}$

$x^2+5x+\frac{25}{4}=\frac{37}{4}$; $\left(x^2+5x+\frac{25}{4}\text{ is a perfet squre.}\right)$

$\left(x+\frac{5}{2}\right)^2=\frac{37}{4}$

$\left(x+\frac{5}{2}\right)=\sqrt{\frac{37}{4}}$ or $\left(x+\frac{5}{2}\right)=-\sqrt{\frac{37}{4}}$

$x=-\frac{5}{2}+\sqrt{\frac{37}{4}}$ or $x=-\frac{5}{2}-\sqrt{\frac{37}{4}}$

Therefore $x=\frac{-5+\sqrt{37}}{2}$ or $x=\frac{-5-\sqrt{37}}{2}$.

Example 12 Solve $3x^2+12x+6=0$.

Solution: First divide all terms by 3 so that the coefficient of x^2 is + 1.

$3x^2+12x+6=0$ becomes $x^2+4x+2=0$

$x^2+4x=-2$ (*Shifting the constant term to the right side*)

$x^2+4x+4=-2+4$ (*half of 4 is 2 and its square is 4*)

$(x+2)^2=2$ ($x^2+4x+4=(x+2)^2$, *a perfect square*)

$(x+2)=\pm\sqrt{2}$

$x=-2\pm\sqrt{2}$

Therefore $x=-2-\sqrt{2}$ or $x=-2+\sqrt{2}$.

Example 13 Solve $3x^2+12x+15=0$.

Solution: First divide all terms by 3 so that the coefficient of x^2 is + 1.

$3x^2+12x+15=0$ becomes $x^2+4x+5=0$

$x^2+4x=-5$ (*Shifting the constant term to the right side*)

$x^2+4x+4=-5+4$ (*half of 4 is 2 and its square is 4*)

$(x+2)^2=-1$ ($x^2+4x+4=(x+2)^2$, *a perfect square*)

$(x+2)=\pm\sqrt{-1}$

Since $\sqrt{-1}$ is not a real number, we conclude that the quadratic equation does not have a real solution.

Example 14 Solve $2x^2+4x+2=0$.

Solution: $2x^2+4x+2=0$ becomes

$x^2+2x+1=0$ (*Dividing all terms by 2*)

$(x+1)^2=0$ ($x^2+2x+1=(x+1)^2$ *is a perfect square*)

$(x+1)=0$

Therefore $x=-1$ is the only solution.

Exercise 2.5

1 Solve each of the following quadratic equations by using the method of completing the square.

a $x^2 - 6x + 10 = 0$ b $x^2 - 12x + 20 = 0$ c $2x^2 - x - 6 = 0$

d $2x^2 + 3x - 2 = 0$ e $3x^2 - 6x + 12 = 0$ f $x^2 - x + 1 = 0$

2 Find the solution set for each of the following equations.

a $20x^2 + 10x - 8 = 0$ b $x^2 - 8x + 15 = 0$ c $6x^2 - x - 2 = 0$

d $14x^2 + 43x + 20 = 0$ e $x^2 + 11x + 30 = 0$ f $2x^2 + 8x - 1 = 0$

3 Reduce these equations into the form $ax^2 + bx + c = 0$ and solve.

a $x^2 = 5x + 7$ b $3x^2 - 8x = 15 - 2x + 2x^2$

c $x(x-6) = 6x^2 - x - 2$ d $8x^2 + 9x + 2 = 3(2x^2 + 6x) + 2(x-1)$

e $x^2 + 11x + 30 = 2 + 11x(x+3)$

Solving quadratic equations using the quadratic formula

Following the method of completing the square, you next develop a general formula that can serve for checking the existence of a solution to a quadratic equation, and for solving quadratic equations.

To derive the general formula for solving $ax^2 + bx + c = 0, a \neq 0$, we proceed using the method of completing the square.

The following Group Work will help you to find the solution formula of the quadratic equation $ax^2 + bx + c = 0, a \neq 0$, by using the completing the square method.

Group Work 2.6

Consider $ax^2 + bx + c = 0, a \neq 0$

1 First divide each term by a.

2 Shift the constant term $\frac{c}{a}$ to the right.

3 Add the square of half of the middle term to both sides.

4 Do you have a perfect square?

5 Solve for x by using completing the square.

6 Do you observe that $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$?

7 What will be the roots of the quadratic equation $ax^2 + bx + c = 0$?

For a general quadratic equation of type $ax^2 + bx + c = 0, a \neq 0$, by applying the method of completing the square, you can conclude that the roots are $r_1 = \frac{-b - \sqrt{b^2 - 4ac}}{2a}$ and $r_2 = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$.

Therefore, the solution set is $\left\{\frac{-b - \sqrt{b^2 - 4ac}}{2a}, \frac{-b + \sqrt{b^2 - 4ac}}{2a}\right\}$.

From the above discussions, what do you observe about $b^2 - 4ac$ in $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$?

ACTIVITY 2.11

In $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$, discuss the possible conditions for x when,

a $b^2 - 4ac > 0$ b $b^2 - 4ac = 0$ c $b^2 - 4ac < 0$

Note: If any quadratic equation $ax^2 + bx + c = 0, a \neq 0$ has a solution, then the solution is determined by $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ and

1 if $b^2 - 4ac > 0$, then $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ represents two numbers, namely $x = \frac{-b - \sqrt{b^2 - 4ac}}{2a}$ and $x = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$.

Therefore, the equation has two solutions.

2 if $b^2 - 4ac = 0$ then $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-b}{2a}$ is the only solution.

Therefore, the equation has only one solution.

3 if $b^2 - 4ac < 0$, then $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ is not defined in $\mathbb{R}$.

Therefore, the equation does not have any real solution.

The expression $b^2 - 4ac$ is called the discriminant or discriminator. It helps to determine the existence of solutions.

Example 15 Using the discriminant, check to see if the following equations have solution(s), and solve if there is a solution.

a $3x^2 - 5x + 2 = 0$ b $x^2 - 8x + 16 = 0$ c $-2x^2 - 4x - 9 = 0$

Solution:

a $3x^2 - 5x + 2 = 0$; $a = 3, b = -5$ and $c = 2$.

So $b^2 - 4ac = (-5)^2 - 4(3)(2) = 1 > 0$

Therefore, the equation $3x^2 - 5x + 2 = 0$ has two solutions.

Using the quadratic formula, $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$$x = \frac{-(-5) - \sqrt{(-5)^2 - 4(3)(2)}}{2(3)} \text{ or } x = \frac{-(-5) + \sqrt{(-5)^2 - 4(3)(2)}}{2(3)}$$

$$x = \frac{5 - \sqrt{25 - 24}}{6} \text{ or } x = \frac{5 + \sqrt{25 - 24}}{6}$$

$$x = \frac{5 - \sqrt{1}}{6} \text{ or } x = \frac{5 + \sqrt{1}}{6}$$

$$x = \frac{5 - 1}{6} \text{ or } x = \frac{5 + 1}{6}$$

$$x = \frac{4}{6} \text{ or } x = \frac{6}{6}$$

Therefore $x = \frac{2}{3}$ or $x = 1$.

b In $x^2 - 8x + 16 = 0$, $a = 1, b = -8$ and $c = 16$

So $b^2 - 4ac = (-8)^2 - 4(1)(16) = 0$

Therefore, the equation $x^2 - 8x + 16 = 0$ has only one solution.

Using the quadratic solution formula, $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-b}{2a}$

$$x = \frac{-(-8)}{2(1)} = 4$$

Therefore the solution is $x = 4$.

c In $-2x^2 - 4x - 9 = 0$, $a = -2, b = -4$ and $c = -9$

So $b^2 - 4ac = (-4)^2 - 4(-2)(-9) = -56 < 0$

Therefore the equation $-2x^2 - 4x - 9 = 0$ does not have any real solution.

Exercise 2.6

1 Solve each of the following quadratic equations by using the quadratic solution formula.

a $x^2 + 8x + 15 = 0$ b $3x^2 - 12x + 2 = 0$ c $4x^2 - 4x - 1 = 0$

d $x^2 + 3x - 2 = 0$ e $5x^2 + 15x + 45 = 0$ f $3x^2 - 4x - 2 = 0$

2 Find the solution set for each of the following equations.

a $x^2 + 6x + 8 = 0$ b $9 + 30x + 25x^2 = 0$ c $9x^2 + 15 - 3x = 0$

d $4x^2 - 36x + 81 = 0$ e $x^2 + 2x + 8 = 0$ f $2x^2 + 8x + 1 = 0$

3 Reduce the equations into the form $ax^2 + bx + c = 0$ and solve.

a $3x^2 = 5x + 7 - x^2$ b $x^2 = 8 + 2x + 2x^2$

c $x^2 - 2(x-6) = 6 - x$ d $x^2 - 4 + x(1 + 6x) + 2(x-1) = 4x - 3$

e $4 - 8x^2 + 6x = 2x(x+3) + 2x$

4 A school community had planned to reduce the number of grade 9 students per class room by constructing additional class rooms. However, they constructed 4 less rooms than they planned. As the result, the number of students per class was 10 more than they planned. If there are 1200 grade 9 students in the school, determine the current number of class rooms and the number of students per class.

The relationship between the coefficients of a quadratic equation and its roots

You have learned how to solve quadratic equations. The solutions to a quadratic equation are sometimes called roots. The general quadratic equation $ax^2 + bx + c = 0, a \neq 0$ has roots (solutions)

$r_1 = \frac{-b - \sqrt{b^2 - 4ac}}{2a}$ and $r_2 = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$.

ACTIVITY 2.12

1 If $r_1 = \frac{-b - \sqrt{b^2 - 4ac}}{2a}$ and $r_2 = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$ are roots of the quadratic equation $ax^2 + bx + c = 0, a \neq 0$ then

a Find the sum of the roots $(r_1 + r_2)$.

b Find the product of the roots $(r_1 r_2)$.

Appendix 8 New Textbook on "Quadratic Equations" (G9 Unit 3)

3.3.2 Quadratic equations

Activity 3.4

Multiply the left side of each of the following. What do you get? What is the difference between these equations and linear equations?

1. $(x+3)(x-2)=0$
2. $(5x+1)(2x+4)=2$
3. $\left(\frac{1}{2}x-3\right)(x+5)=0$

Definition 3.3

An equation of the form $ax^2+bx+c=0$ where a, b, c, $\in$ R and $a \neq 0$ is a quadratic equation. Here, a is called the leading coefficient, b is the middle term and c is the constant term.

Solving quadratic equations

There are three basic methods for solving quadratic equations: factorization (if possible), completing the square and the quadratic formula method.

Factorization method 1

Activity 3.5

Find two integers such that

a. the sum is 5 and the product is 6.
b. the sum is 1 and the product is -12.

How to solve a quadratic equation by factorization method?

1. Put all terms on one side of the equal sign, leaving zero on the other side.
2. Factorize the equation.

3. Set each factor equal to zero.
4. Solve each of these equations.
5. Check by inserting your answer in the original equation.

Example 1

Solve the quadratic equation $x^2+3x=0$.

$$x(x+3)=0$$
$$x=0 \text{ or } x+3=0$$
$$x=0 \text{ or } x=-3$$

Hence, the solution of the quadratic equation is $x=0,\ x=-3$.

Example 2

Solve the quadratic equation: $x^2-6x-16=0$

Solution:

Factorizing this (find two numbers whose sum is -6 and product is -16), we have -8 and 2. Hence, $(x-8)(x+2)=0$

$$x-8=0 \text{ or } x+2=0$$

Recall that ab = 0 if and only if a = 0 or b = 0

$$x=8,\ x=-2$$

Hence, the solution of the quadratic equation is $x=8,\ x=-2$.

Exercise 3.10

Solve the following quadratic equations using factorization method.

a. $x^2-5x=0$
b. $x^2+7x+10=0$
c. $x^2+x-6=0$
d. $x^2-4x+3=0$

Factorization Method 2

Example 1

Solve the quadratic equation $x^2+6x+9=0$

Solution:

$(x+3)(x+3)=(x+3)^2=0$ (Factorizing: sum = 6 and product = 9).

$$x=-3$$

Hence, $x=-3$ is the only solution.

Example 2

Solve the quadratic equation $x^2-9=0$

Solution:

$(x-3)(x+3)=0$ (Factorizing: sum = 0 and product= 9)

$$x=3 \text{ or } x=-3$$

Hence, the solution of the quadratic equation is $x=3,\ x=-3$.

Example 3

Solve the quadratic equation $4x^2+4x+1=0$

Solution:

Re-writing $4x^2+2x+2x+1=0$

$$2x(2x+1)+1(2x+1)=0$$
$$(2x+1)(2x+1)=0$$
$$(2x+1)^2=0$$
$$x=-\frac{1}{2}$$

Hence, the solution of the quadratic equation is $x=-\frac{1}{2}$.

Exercise 3.11

Solve the following quadratic equations using factorization method.

a. $x^2+10x+25=0$
b. $x^2-8x+16=0$
c. $x^2-4=0$
d. $9x^2-6x+1=0$

Completing the square method

Example 1

Is it possible to solve $x^2+6x+4=0$ using factorization method?

Solution:

Since there are no two integers whose sum is equal to 6 and product is equal to 4, this quadratic equation may not be solved using factorization method. Hence, we need another method to solve the equation.

$$x^2+6x+9+4-9=0$$
$$(x+3)^2-5=0$$
$$(x+3)^2=5$$
$$x+3=\pm\sqrt{5}$$
$$x=-3\pm\sqrt{5}$$

Completing the square is where we take the quadratic equation

$ax^2+bx+c=0, a\neq 0$ and convert it into $\left(x+\frac{b}{2a}\right)^2+\frac{4ac-b^2}{4a^2}=0$ as follows:

$x^2+\frac{b}{a}x+\frac{c}{a}=0$ (*since* $a\neq 0$)

$(x^2+\frac{b}{a}x+\frac{b^2}{4a^2})+\frac{c}{a}-\frac{b^2}{4a^2}=0.$ Taking half of the coefficient of the middle term and squaring it and adding its opposite). The expression in the bracket is a perfect square. Hence, after simplifying, we have

$\left(x+\frac{b}{2a}\right)^2+\frac{4ac-b^2}{4a^2}=0$ ..... (*)

Equivalently, $ax^2+bx+c=0$ if and only if $\left(x+\frac{b}{2a}\right)^2+\frac{4ac-b^2}{4a^2}=0$

Example 2

Solve $x^2 + 4x + 4 = 0$ using completing the square method.

Solution:

$(x^2 + 4x + 4) + 4 - 4 = 0$ (Adding the square of half of the coefficient of the middle term (4) and its opposite.

$(x + 2)^2 - 0 = 0$. (Writing as a perfect square)

$(x + 2)^2 = 0$

$x = -2$

Example 3

Solve $x^2 + 6x + 7 = 0$ using completing the square method.

Solution:

$x^2 + 6x + 9 + 7 - 9 = 0$ (Adding the square of half of the coefficient of the middle term (6) and its opposite)

$(x^2 + 6x + 9) + 7 - 9 = 0$ (Colleting those terms which sum up as a perfect square)

$(x + 3)^2 - 2 = 0$. (Writing as a perfect square)

$(x + 3)^2 = 2$

$x + 3 = \pm\sqrt{2}$ (Taking the square root)

$x = -3 \pm \sqrt{2}$

Therefore, $x = -3 + \sqrt{2}$ and $x = -3 - \sqrt{2}$ are the solutions.

Exercise 3.12

Use completing the square method to solve the following.

a. $x^2 + 4x + 1 = 0$ b. $x^2 - 6x - 5 = 0$

c. $2x^2 + 5x + 3 = 0$

The quadratic formula method

There are quadratic equations that cannot be solved by factorization method. This is generally true when the roots are not rational numbers. Consider the quadratic equation $ax^2 + bx + c = 0$, where $a \neq 0$.

From the completing the square method, we have $\left(x + \frac{b}{2a}\right)^2 + \frac{4ac - b^2}{4a^2} = 0$

Solving for x, $\left(x + \frac{b}{2a}\right)^2 = \frac{b^2 - 4ac}{4a^2}$

$x + \frac{b}{2a} = \pm\sqrt{\frac{b^2 - 4ac}{4a^2}}$

$x = -\frac{b}{2a} \pm \frac{\sqrt{b^2 - 4ac}}{2a}$

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Quadratic formula

For the quadratic equation $ax^2 + bx + c = 0, a \neq 0$, $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

This is the quadratic formula

Example

Solve $x^2 - 6x + 3 = 0$ using the quadratic formula.

Solution:

$1, -6$ and 3 are the values for a, b, and c, respectively in the quadratic formula. Thus,

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$x = \frac{-(-6) \pm \sqrt{(-6)^2 - 4(1)(3)}}{2(1)}$$

$$x = \frac{6 \pm \sqrt{36 - 12}}{2} = \frac{6 \pm \sqrt{24}}{2} = 3 \pm \sqrt{6}$$

Hence, $3 + \sqrt{6}$ and $3 - \sqrt{6}$ are the solutions. Can you solve this using other

methods?

Exercise 3.13

Use quadratic formula to solve the following.

a. $x^2 + 3x + 1 = 0$ b. $x^2 + 5x - 2 = 0$ c. $2x^2 - 3x - 1 = 0$

Discriminant

Remark: When using the quadratic formula, you should be aware of three possibilities. These three possibilities are distinguished by a part of the formula called the discriminant. The discriminant is the value under the radical sign which is $b^2 - 4ac$. A quadratic equation with real numbers as coefficients can have the following:

The roots of the quadratic equation are $x = \frac{-b \pm \sqrt{D}}{2a}$, where $D = b^2 - 4ac$.

If $D > 0$, then the roots are real and distinct (unequal); the quadratic equation has two distinct roots.

If $D = 0$, then the roots are real and equal (coincident); the quadratic equation has exactly one real root.

If $D < 0$, then there are no real roots.

Example 1

Check whether $x^2 + 2x + 2 = 0$ has distinct real roots, one real root or no real roots. If root exists, find it.

Solution:

Here, $a = 1$, $b = 2$ and $c = 2$.

Since $b^2 - 4ac = 4 - 8 = -4 < 0$, no need to find the roots. The following is to show that the roots are not real number.

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$x = \frac{-(2) \pm \sqrt{(2)^2 - 4(1)(2)}}{2(1)}$$

$x = \frac{-2 \pm \sqrt{4-8}}{2} = \frac{-2 \pm \sqrt{-4}}{2}$ are not real numbers.

Example 2

Check whether $x^2 + 18x + 81 = 0$ has distinct real roots, one real root or no real roots. If root exists, find it.

Solution:

Here, $a = 1, b = 18$ *and* $c = 81$,

$D = b^2 - 4ac = 18^2 - 4(1)(81) = 324 - 324 = 0$. Since $D = 0$, the equation has exactly one root. Solving the equation,

$(x + 9)^2 = 0$

$x = -9$

Example 3

Check whether $x^2 + 4x + 3 = 0$ has distinct real roots, one real root or no real roots. If root exists, find it.

Solution:

Here, $a = 1, b = 4$ and $c = 3$, and then

$D = b^2 - 4ac = 4^2 - 4(3) = 16 - 12 = 4$

Since $D > 0$, the equation has two distinct real roots. Solving the equation,

$(x + 1)(x + 3) = 0$

$x = -1$ and $x = -3$

Exercise 3.14

Check whether the following quadratic equations have two real roots, one real root or no real roots. If any real root exists, find it.

a. $x^2 + 2x + 3 = 0$ b. $x^2 + 12x + 36 = 0$ c. $x^2 + 8x + 7 = 0$

Appendix 9 Minutes of Discussion of the Third JCC Meeting (March 29, 2022)

Minutes of Discussion
of
The Third Joint Coordinating Committee Meeting
on
The Project for Mathematical Understanding for
Science and Technology
(MUST)

Agreed Upon Between

Ministry of Education
Federal Democratic Republic of Ethiopia

and

Japan International Cooperation Agency

Addis Ababa
29 March 2022

Theodros Shewarget Belew (PhD)
Director General for
Curriculum Development
and Research

Dr. Theodros Shewarget
Director General
Ministry of Education
Federal Democratic Republic of Ethiopia

Dr. Katsuki Morihara
Chief Representative
JICA Ethiopia Office

JICA
Japan International Cooperation Agency

The Ministry of Education (MoE), in cooperation with Japan International Cooperation Agency (JICA), convened the third Joint Coordinating Committee meeting on the "Project for Mathematical Understanding for Science and Technology" on 29 March 2022 at CDID meeting room in the MoE annex building. The meeting was chaired by Dr. Theodros Shewarget, Director General.

The meeting was attended by the Ministry of Education, JICA Ethiopia Office and the JICA Experts for the Project. A list of attendants is as below. The meeting discussed following agenda and reached the conclusions as recorded.

Date: 29 March 2022 (Tuesday)
Time: 8:30~9:30am
Venue: CDID Meeting Room, MoE

Attendants:

Dr. Theodros Shewarget	Director General, MoE
Ms. Zafu Abraha	Director, CDID, MoE
Dr. Katsuki Morihara	Chief Representative, JICA Ethiopia Office
Ms. Mai Toguchi	Representative, JICA Ethiopia Office
Mr. Biruk Zenebe	Program Officer, JICA Ethiopia Office
Mr. Ippei Shimizu	Mathematics and Science Education Advisor to MoE
Dr. Norimichi Toyomane	JICA Expert, Team Leader
Ms. Nahoko Chiku	JICA Expert, Deputy Team Leader
Ms. Michiru Yabuta	JICA Expert
Ms. Yumi Sekiguchi	JICA Long-Term Expert
Mr. Takele Alemu	Project Research Assistant

Agenda:

1. To review MUST progress from 2021 until 2022
2. To review and decide MUST activity plan from 2022 until 2023

Discussion:

Dr. Toyomane, Team Leader of the JICA Expert Team, first made a brief presentation on the two agenda. Main points of the following discussion are summarized as follows:

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Director General for
Curriculum Development
and Research

JICA
Japan International Cooperation Agency

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1. Dr. Theodros, Director General, opened discussion thanking JICA for its continued technical support since SMASEE project. He particularly appreciated MUST for its quality assurance of secondary mathematics textbooks. He also pointed out the necessity to extend MUST project beyond September 2023 to evaluate the impact of the new textbooks after they are fully implemented.

2. In response to him, Dr. Morihara, Chief Representative of JICA Ethiopia Office, expressed his appreciation of MoE's cooperation in the past two difficult years. He emphasized the importance of carrying out planned activities as planned to achieve the project objectives.

3. Ms. Zafu, Director of CDID, also appreciated JICA's commitment and support, which had been highly effective to improve the quality of math textbooks, as part of the ongoing curriculum reform that is a historic undertaking and a long journey.

4. CDID and the JICA Expert Team for MUST confirmed that MUST could continue its support to the Textbook Developers from April 2022 to March 2023 to further improve the G9-G12 Textbook Drafts as the joint products of CDID-MUST collaboration.

5. CDID and the JICA Expert Team for MUST confirmed that to improve the G9-G12 Textbook Drafts further, MUST would organize six more face-to-face Workshops inviting the Textbook Developers between April 2022 and February 2023, on a more or less bimonthly basis.

6. CDID and the JICA Expert Team for MUST confirmed that the same modality used for the Workshop in February 2022 would be applied to the six Workshops above: CDID would mobilize the Textbook Developers through the Center of Excellence while JICA would bear the workshop costs (DSA/accommodation, transportation, venue). If financial matters should arise, both parties agreed to continue discussion on the matters to find the solutions.

7. CDID and the JICA Expert Team for MUST confirmed that monitoring by MUST would be implemented in Addis Ababa only for the time being.

8. CDID and the JICA Expert Team for MUST confirmed that MUST would target two pilot schools and two non-pilot schools selected from Addis Ababa.

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9. CDID and the JICA Expert Team for MUST confirmed that MUST monitoring would be conducted by the following team:

Director General
Director CDID
CDID Expert
Addis Ababa City Education Bureau Expert(s)
Evaluator(s)
Textbook Developer(s)
JICA Expert Team for MUST

10. CDID and the JICA Expert Team for MUST confirmed that MUST monitoring would include following activities:

Pilot Schools	Non-Pilot Schools
Before Piloting 1. Lesson observation (April-May 2022) 2. Model lesson by model teacher(s) and video shooting (May 2022) 3. Pre-Piloting training for Math teachers (August 2022) During Piloting 4. Lesson observation (Sept 2022-March 2023) 5. Achievement Test 1 (Oct 2022) 6. Unit-end Tests (after each Unit is finished) 7. Achievement Test 2 (April 2023) 8. Special support to Model Teachers (Sept 2022-March 2023) 9. Model lesson by Model Teacher(s) and video shooting (April 2023) 10. Experience Sharing Workshop (June 2023)	Before Piloting 1. Lesson observation (April-May 2022) During Piloting 2. Lesson observation (Sept 2022-March 2023, as needed) 3. Achievement Test 1 (Oct 2022) 4. Unit-end Tests (after each Unit is finished) 5. Achievement Test 2 (April 2023)

11. CDID and the JICA Expert Team for MUST confirmed that, if necessary, CDID and MUST would conduct technical consultation once a month with other piloting regions on G9-G10 Textbooks.

12. CDID and the JICA Expert Team for MUST confirmed that CDID would invite MUST to present at a Math session in the CDID-organized ToT Training for regional teachers on the new textbooks to be scheduled in July or August 2022.

Theodros Shewarget Belew (PhD)
Director General for
Curriculum Development
and Research

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13. CDID and the JICA Expert Team for MUST confirmed that CDID and MUST would organize a nation-wide Workshop to share regions' experiences of the piloting of G9-G10 Textbooks in February 2023.

14. In relation to school monitoring described in points 9 and 10 above, JICA Advisor to MoE explained that JICA Experts were assigned to MUST under a tightly planned schedule so that they could not be flexible in adjusting the dates of their monitoring activities. He therefore requested CDID to respect their planned schedule for monitoring. CDID accepted this explanation. In addition, both parties agreed that the JICA Expert Team would inform the Ethiopian monitoring team of the schedule of each monitoring activity well in advance in order for the Ethiopian team members to be able to participate in the activities.

15. JICA Experts requested CDID to provide the final drafts of the textbooks before they would be validated in mid-April. CDID promised to negotiate with Hawassa University on this issue and, at the same time, cordially invited the JICA Expert Team to attend the validation workshops.

16. Director of CDID again raised the issue of impact evaluation after September 2023. JICA Advisor to MoE, citing the words of Chief Representative of JICA Ethiopia Office, explained that this possibility should be explored after MUST had produced tangible outputs. He added that JICA would discuss this issue as needed. CDID accepted this explanation.

17. Director of CDID concluded the meeting appreciating JICA's continued cooperation and thanking the participants for their concern and kind attendance.

Theodros Shewarget Belew (PhD)
Director General for
Curriculum Development
and Research

Japan International Cooperation Agency

Appendix 10 Minutes of Discussion of the Fourth JCC Meeting (Nov 24, 2022)

Minutes of Discussion
of
The Fourth Joint Coordinating Committee Meeting
on
The Project for Mathematical Understanding for
Science and Technology
(MUST)

Agreed Upon Between

Ministry of Education
Federal Democratic Republic of Ethiopia

and

Expert Team
Japan International Cooperation Agency

Addis Ababa
24 November 2022

Zafu Abraha Yeibiyo
Natural Science Education
Curriculum Desk Head

Ms. Zafu Abraha
Natural Science Education Desk Head
Curriculum Development and Implementation Directorate
Ministry of Education
Federal Democratic Republic of Ethiopia

Dr. Norimichi Toyomane
Team Leader
JICA Expert Team for MUST

The Ministry of Education (MoE), in cooperation with Japan International Cooperation Agency (JICA), convened the fourth Joint Coordinating Committee meeting on the "Project for Mathematical Understanding for Science and Technology" on 24 November 2022 at CDID in the MoE annex building. Since State Minister and Chief Executive Officer of MoE were both on duty abroad, Chief Executive Officer delegated Ms. Zafu Abraha, Natural Science Education Desk Head of CDID, to chair the meeting and sign the minutes of the meeting.

The meeting was attended by the Ministry of Education, Addis Ababa Education Bureau, JICA Ethiopia Office and the JICA Experts for the Project. A list of attendants is as below. The meeting discussed following agenda and reached the conclusions as recorded.

Date: 24 November 2022 (Thursday)
Time: 9:00~11:10am
Venue: CDID, MoE

Attendants:

Ms. Zafu Abraha	Natural Science Education Desk Head, CDID, MoE
Mr. Getachew Talema	Director, Curriculum, Addis Ababa Education Bureau
Mr. Tesfaye Sileshi	Mathematics Expert, CDID, MoE
Ms. Megumi Hirose	Senior Representative, JICA Ethiopia Office
Ms. Ikumi Ishidate	Representative, JICA Ethiopia Office
Mr. Biruk Zenebe	Program Officer, JICA Ethiopia Office
Mr. Ippei Shimizu	Mathematics and Science Education Advisor to MoE
Dr. Norimichi Toyomane	JICA Expert, Team Leader
Ms. Yumi Sekiguchi	JICA Long-Term Expert
Mr. Takele Alemu	Project Research Assistant

Agenda:

1. To review MUST progress from March 2022 to November 2022
2. To decide MUST activity plan from December 2022 to August 2023

Discussion:

Ms. Zafu, Natural Science Education Desk Head of CDID, opened the meeting expressing MoE's appreciation of MUST project. Dr. Toyomane, Team Leader of the JICA Expert Team, then made a brief presentation on the two agenda. Subsequently, Ms. Zafu presented her overview of MoE's curriculum reform and the intermediate achievements of MUST project, appreciating its various contributions made so far and clarifying the challenges lying ahead. Main points of the following discussion are summarized as follows:

1. Ms. Zafu, Natural Science Education Desk Head of CDID, pointed out that assessment part is missing from the proposed Annual Plan. Dr. Toyomane, Team Leader of the JICA Expert Team, replied that the Annual Plan format would be modified to indicate assessment explicitly.

2. Natural Science Education Desk Head of CDID questioned the purpose of the Achievement Tests particularly with regard to the new textbooks. Team Leader of the JICA Expert Team explained that the Achievement Tests were being conducted to assess the effects of the new textbooks on the students' achievement in mathematics and not intended to make any inputs to the new textbooks.

3. Mr. Getachew, Director of Addis Ababa Education Bureau, asked how G11 and G12 textbooks could be revised without piloting. Team Leader of the JICA Expert Team explained that JICA experts carefully reviewed the drafts from various viewpoints and made comments for the textbook developers to consider.

4. Director of Addis Ababa Education Bureau asked what the main gap was with teachers as observed in the classroom lessons. Team Leader of the JICA Expert Team replied that the common shortcoming was the insufficient time given to the students to solve exercise questions for themselves.

5. Director of Addis Ababa Education Bureau also asked what the teachers' positive response was about the new textbooks. Team Leader of the JICA Expert Team answered that teachers most appreciated the ease of organizing lessons using the new textbooks.

6. Director of Addis Ababa Education Bureau asked the reason why no MUST activities had been done to support regional pilot activities. Team Leader of the JICA Expert Team replied that it was because there had been no request in this regard from the regions so far.

7. Mr. Tesfaye, Mathematics Expert of CDID, questioned what MUST would propose based on the results of the Achievement Tests. Team Leader of the JICA Expert Team

explained that the purpose of the Achievement Tests was not to directly contribute to the improvement of the textbooks but to justify the whole MUST project by indicating the positive impact of the new textbooks on students' level of learning.

8. Mathematics Expert of CDID asked what MUST would propose about teachers' pedagogy. Team Leader of the JICA Expert Team answered that the most important proposal MUST was making to the teachers was the 20-20 principle, that is, 20 minutes are for teachers to teach, and 20 minutes for students to think and solve exercise questions by themselves.

9. Ms. Hirose, Senior Representative of JICA Ethiopia Office, asked Natural Science Education Curriculum Desk Head of CDID to confirm MoE's time schedule for finalizing the new textbooks. Natural Science Education Curriculum Desk Head of CDID confirmed that MoE would finalize the new textbooks in late February 2023.

10. Senior Representative of JICA Ethiopia Office pointed out that advancing the printing schedule by a few months would reduce MUST's inputs to the development of the new textbooks. Natural Science Education Curriculum Desk Head of CDID accepted the condition, saying that printing of the new textbooks would take a long time.

11. Mr. Shimizu, Mathematics and Science Education Advisor to MoE, asked Natural Science Education Curriculum Desk Head of CDID by what time JICA expert team should submit their final comments on the draft textbooks and teacher's guides. Natural Science Education Curriculum Desk Head of CDID answered that their final comments should be submitted by the end of December 2022 in written form. She added that MoE would cross-check the comments with the comments given by the national monitoring teams and ask the textbook developers to incorporate them by the end of January 2023.

12. CDID and the JICA Expert Team for MUST confirmed that in order to align with CDID's activity schedule, particularly its earlier start of printing, the 7th Workshop with the Textbook Developers, originally scheduled in early December 2022, would be held on December 30, 31, and January 1, and the 8th Workshop scheduled in February 2023 would be cancelled. Both parties also agreed that during the 7th Workshop, no lesson observation would be implemented to secure enough working time for the Textbook Developers.

13. CDID and the JICA Expert Team for MUST confirmed that MUST could continue its lesson observation and other activities at the pilot and non-pilot schools even after the finalization of the teaching materials started, in order to advise teachers on effective

utilization of the new textbooks and to collect data and information to be input to the math teachers' induction to the new textbooks planned later in 2023.

14. Mathematics and Science Education Advisor to MoE strongly urged CDID and AAEB to participate in the lesson observation being conducted by MUST.

15. Natural Science Education Curriculum Desk Head of CDID questioned the utility of the Achievement Tests being planned by MUST saying that their results could not be generalized if only five secondary schools in Addis Ababa were targeted. Senior Representative of JICA Ethiopia Office clarified that the Achievement Tests were intended to justify the whole MUST project and, eventually, JICA's future program in Ethiopia. Mr. Biruk, Program Officer of JICA Ethiopia Office, added that the Achievement Tests were not intended to generalize their results to say something general about the Ethiopian students' achievement in mathematics.

16. Director of Addis Ababa Education Bureau suggested that Unit-End Test results should be analyzed. Team Leader of the JICA Expert Team replied that MUST would do so.

17. Director of Addis Ababa Education Bureau asked if the proposed A-D-E-E was the only possible structure. Team Leader of the JICA Expert Team answered that it was one of many alternative structures and specifically adopted by MUST to accommodate the original format used by the textbook developers.

18. Mathematics and Science Education Advisor to MoE once again urged Director of Addis Ababa Education Bureau and Mathematics Expert of CDID to join the lesson observation being conducted by MUST, saying that its ultimate goal was to scale up the teachers' effective usage of the new structured textbooks and eventually to improve students' performances.

19. In her closing remarks, Senior Representative of JICA Ethiopia Office, first agreed with MUST's motto of "We improve textbooks to improve students' achievement." She then pointed out that once textbooks were improved, teachers' capacity building at schools would then become important. For that purpose, she pleaded for permission of video shooting at schools.

20. Natural Science Education Curriculum Desk Head of CDID concluded the meeting appreciating JICA's continued cooperation and thanking the participants for their kind attendance.

Appendix 11 Minutes of Discussion of the Fifth JCC Meeting (May 9, 2023)

Minutes of Discussion
of
The Fifth Joint Coordinating Committee Meeting
on
The Project for Mathematical Understanding for
Science and Technology
(MUST)

Agreed Upon Between

Ministry of Education
Federal Democratic Republic of Ethiopia

and

Expert Team
Japan International Cooperation Agency

Addis Ababa
9 May 2023

Dr. Theodros Shewarget
Lead Executive Officer
Ministry of Education
Federal Democratic Republic of Ethiopia

Dr. Norimichi Toyomane
Team Leader
JICA Expert Team for MUST

The Ministry of Education (MoE), in cooperation with Japan International Cooperation Agency (JICA), convened the fifth Joint Coordinating Committee meeting on the "Project for Mathematical Understanding for Science and Technology" on 9 May 2023 at the Conference Hall in the MoE annex building.

The meeting was attended by the Ministry of Education, JICA Ethiopia Office and the JICA Experts for the Project. A list of attendants is as below. The meeting discussed following agenda and reached the conclusions as recorded.

Date: 9 May 2023 (Tuesday)
Time: 9:00~10:30 am
Venue: Conference Hall, MoE

Attendants:

Dr. Theodros Shewarget	Lead Executive Officer, MoE
Ms. Zafu Abraha	Natural Science Education Curriculum Desk Head, CDID, MoE
Mr. Tesfaye Sileshi	Mathematics Expert, CDID, MoE
Mr. Shintaro Takano	Senior Representative, JICA Ethiopia Office
Mr. Biruk Zenebe	Program Officer, JICA Ethiopia Office
Ms. Junko Nakazawa	Mathematics and Science Education Advisor to MoE
Dr. Norimichi Toyomane	JICA Expert, Team Leader
Ms. Nahoko Chiku	JICA Expert, Deputy Team Leader
Dr. Etsutaro Tanaka	JICA Expert
Ms. Yumi Sekiguchi	JICA Long-Term Expert.
Mr. Takele Alemu	Project Research Assistant

Agenda:

1. To review MUST progress from December 2022 to April 2023
2. To decide MUST activity plan from May 2023 to August 2023

Discussion:

Dr. Theodros, Lead Executive Officer of MoE, opened the meeting expressing MoE's appreciation of MUST project, particularly its convincing the people of the merit of the A-D-

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E-E structure. Dr. Toyomane, Team Leader of the JICA Expert Team, then made a presentation on the two agenda, followed by another brief presentation by Ms. Sekiguchi, JICA Long-Term Expert, about the Experience Sharing Workshop held on 6 May 2023. Subsequently, the floor was opened to comments and questions. Main points of the discussion are summarized as follows:

1. Dr. Theodros, Lead Executive Officer, asked the JICA Expert Team how it evaluated the final version of the textbooks. Dr. Toyomane, Team Leader of the JICA Expert Team, replied that they were not perfect but had accomplished the highest level they could reach under the given conditions.

2. Lead Executive Officer asked the JICA Expert Team to clarify the difference between the teachers' meetings and the experience sharing workshops. Team Leader of the JICA Expert Team explained that the teachers' meetings would be routinely held by teachers themselves whereas the experience sharing workshops would be held once a year or so on special occasions for target schools/areas by someone who is not a teacher.

3. Ms. Zafu, Natural Science Education Curriculum Desk Head of CDID, asked the JICA Expert Team's view as to the quality of the final version of the textbooks since there remained some mistakes even with the camera-ready versions. Team Leader of the JICA Expert Team replied that they thought the textbooks achieved 99% level of quality.

4. Natural Science Education Curriculum Desk Head of CDID pointed out that even if teachers implemented the 20-20 principle in their lessons, students did not automatically show better understanding. Team Leader of the JICA Expert Team appreciated the observation, admitting it was true. He answered that something else than giving enough time needed to be done to improve students' achievement and that this issue would be dealt with in the upcoming reports.

5. Natural Science Education Curriculum Desk Head of CDID appreciated that 75% of teachers participating in the experience sharing workshop on 6 May 2023 indicated their willingness to share their experiences under MUST, particularly the rubrics, with other teachers.

6. Natural Science Education Curriculum Desk Head of CDID also thanked to MUST project and JICA for their contributions to Ethiopia. She expressed her intention to scale up the MUST results and experiences to other regions for the next round of curriculum and textbook reform.

7. Lead Executive Officer asked the JICA Expert Team if it would take part in the full implementation of the new textbooks starting in September 2023. Team Leader of the JICA Expert Team explained that it would finish all its activities at the end of August and therefore could not participate in the full implementation. Ms. Chiku, Deputy Team Leader of the JICA Expert Team, added that Ms. Nakazawa, Mathematics and Science Education Advisor to MoE, would continue supporting MoE after MUST project is finished.

8. Natural Science Education Curriculum Desk Head of CDID expressed her appreciation if there would be supportive materials available for teachers about how to better utilize teaching time in class. Deputy Team Leader of the JICA Expert Team explained that necessary materials for the full implementation will be compiled as the Strategy documents, and one material for the Training of Trainers (ToT) will address the issue.

9. Natural Science Education Curriculum Desk Head of CDID, stating that curriculum reform is a cyclic process, expressed her request for JICA to support CDID with the next cycle of curriculum reform.

10. Mr. Biruk, Program Officer of JICA Ethiopia Office, congratulated CDID and MUST project on their achievement. He explained that JICA would continue collaboration with MoE toward the next stage, particularly through Ms. Nakazawa and another advisor to be assigned soon.

11. Ms. Nakazawa, Mathematics and Science Education Advisor to MoE, understood that for teachers it would not be easy to teach according to the A-D-E-E structure. However, she would look forward to the full implementation of the new textbooks because she observed in some lessons that teachers paid attention to individual students and checked their solutions, a phenomenon she never observed in other African countries. She also noticed that one teacher quickly modified his way of teaching after he received comments from experts from Sub-City and Addis Ababa Education Bureau who observed the teacher's lesson using the rubrics. By witnessing this, she was convinced that subject teachers' meetings using the rubrics supported by principal/vice principals would be the key to the continuous professional development that is sustainable.

12. Deputy Team Leader of the JICA Expert Team suggested MoE to initiate a national campaign to urge students to bring their textbooks to classes as one of the measures to promote the utilization of the new textbooks in the full implementation phase.

13. Mr. Takano, Senior Representative of JICA Ethiopia Office, appreciated the active discussion held throughout the meeting. Impressed by the very positive responses by the teachers who participated in the experience sharing workshop, he hoped that there would emerge good leaders from among them. He also appreciated the positive results gained from various tests, which might strongly encourage the teachers. He stressed that JICA would continue supporting MoE and proposed to keep close sharing of information. He concluded the meeting with appreciation of cooperation by MoE and CDID.

Appendix 12 Minutes of Discussion of the Sixth JCC Meeting (July 24, 2023)

Minutes of Discussion
of
The Sixth Joint Coordinating Committee Meeting
on
The Project for Mathematical Understanding for
Science and Technology
(MUST)

Agreed Upon Between

Ministry of Education
Federal Democratic Republic of Ethiopia

and

Expert Team
Japan International Cooperation Agency

Addis Ababa
24 July 2023

Dr. Theodros Shewarget
Lead Executive Officer
Ministry of Education
Federal Democratic Republic of Ethiopia

Dr. Norimichi Toyomane
Team Leader
JICA Expert Team for MUST

The Ministry of Education (MoE), in cooperation with Japan International Cooperation Agency (JICA), convened the sixth Joint Coordinating Committee meeting on the "Project for Mathematical Understanding for Science and Technology" on 24 July 2023 at the Meeting Room of the EMIS Directorate in the MoE annex building.

The meeting was attended by the Ministry of Education, JICA Ethiopia Office and the JICA Experts for the Project. A list of attendants is as below. The meeting discussed following agenda and reached the conclusions as recorded.

Date: 24 July 2023 (Monday)
Time: 9:00~10:00 am
Venue: Meeting Room, MoE

Attendants:

Dr. Theodros Shewarget	Lead Executive Officer, MoE
Ms. Zafu Abraha	Natural Science Education Curriculum Desk Head, CDID, MoE
Mr. Tesfaye Sileshi	Mathematics Expert, CDID, MoE
Dr. Katsuki Morihara	Chief Representative, JICA Ethiopia Office
Mr. Biruk Zenebe	Program Officer, JICA Ethiopia Office
Ms. Ikumi Ishidate	Representative, JICA Ethiopia Office
Ms. Junko Nakazawa	Mathematics and Science Education Advisor to MoE
Dr. Norimichi Toyomane	JICA Expert, Team Leader
Mr. Masato Kamoda	JICA Expert
Ms. Yumi Sekiguchi	JICA Long-Term Expert
Mr. Takele Alemu	Project Research Assistant

Agenda:

1. To review "Report on the Pilot Monitoring and Evaluation"
2. To review "Project Completion Report"
3. To confirm Project's achievements
4. To discuss the way forward after MUST

Discussion:

1. Ms. Zafu, Natural Science Education Curriculum Desk Head, CDID, opened the meeting appreciating the technical support MUST project provided for MoE's national

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curriculum reform. She expressed her confidence that the revised curriculum would meet the international standards. Since the validity of the new curriculum had yet to be assessed, however, she requested JICA to technically support the implementation and evaluation aspects of the new curriculum and the development of lesson support materials based on the new textbooks for Math and, if possible, science subjects.

2. Dr. Theodros, Lead Executive Officer of MoE, first stated that the cooperation with JICA had successfully achieved the broad task and thanked JICA, MUST project and its team members for their accomplishment. Describing the MUST project as a successful journey, he led our attention to the next steps. Since curriculum is just one part of quality education, he invited all to the next step cooperation in such areas as teachers' quality and other subjects than mathematics like science.

3. Dr. Toyomane, Team Leader of the JICA Expert Team, then made a presentation on the four agenda. In his presentation, he emphasized three main achievements done by MUST project: 1) Introduction of the A-D-E-E structure; 2) Verification of the positive effect of the A-D-E-E structured textbooks and lessons on students' better achievement in mathematics; and 3) Development of a set of resource materials to facilitate teachers to conduct A-D-E-E lessons using the new textbooks. He then made some recommendations for MoE to consider: 1) Distribute the new textbooks; 2) Train teachers on the new teaching method; 3) Support teachers with those activities described in the resource materials; and 4) Initiate a national campaign to urge students to bring the textbooks to school.

4. Ms. Ishidate, Representative of JICA Ethiopia Office, asked the current status of printing of the new textbooks. Lead Executive Officer explained that the printing company had been selected and the contracting process was to be finalized soon.

5. Ms. Sekiguchi, JICA Long-Term Expert, asked if the curriculum documents were still under revision. Lead Executive Officer answered that the documents were finalized and the new textbooks were developed based on them. He added that though their hard copies had not been shared yet, their soft copies were available for sharing.

6. Dr. Morihara, Chief Representative of JICA Ethiopia Office, first congratulated MoE on successful completion of the MUST project. He thanked State Minister for his support and guidance. He explained that education had been one of JICA's top priorities in Ethiopia and MUST project was one such project that utilized strengths of Japan's cooperation. Nonetheless, he added, MUST project had to modify its framework several times due to Covid-19, etc., which was unusual. Despite the difficulties, the MUST project finally succeeded and

made significant achievements, such as the A-D-E-E approach. Strong support, both from the Ethiopian and the Japanese sides, made it possible, he appreciated. He also appreciated the JICA Expert Team's dedication and uncompromising efforts to improve the textbooks, done always working hand in hand with Ethiopian counterparts. As future steps, he proposed to donate 20 million yen for the purpose of textbook printing and to dispatch long-term experts in support of MoE to institutionalize the A-D-E-E approach and ensure the utilization of the new textbooks. He concluded the meeting with a great appreciation of cooperation by MoE and CDID.