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Article

# Factors influencing instructional practices of grade-12 mathematics teachers in Tigray: Lessons from content analysis and socio-economic perspectives of teachers

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**Abstract:** Content analysis is a research tool used to determine the presence of certain words, themes, or concepts within, for example, textbooks. Mathematics textbooks have a significant impact on students' learning due to their role during the instructional processes. Both quantitative and qualitative data from primary and secondary sources were employed using content analysis of grade-12 mathematics textbooks and responses from 23 teachers from schools in three randomly selected zones out of seven. The objective is to identify strengths and/or weaknesses of the textbook and challenges affecting teachers' instructional practices, thereby recommending corrective measures to be taken by stakeholders and policymakers. The nine units/sub-topics of the textbook have been analyzed in terms of coverage, vertical-horizontal relationships, integration, continuity, sequence, and the application of higher-level cognitive objectives. Results from responses to closed-and open-ended questions revealed that major problems with the instructional practices include low interest of students (Mean = 4.22, SD = 1.06) resulting in a high rate of migration, bulky content (Mean = 4.0, SD = 1.14), lack of support from parents (Mean = 3.78, SD = 0.98), shortage of time/period allotment (Mean = 3.65, SD = 1.05), and insufficient training (Mean = 3.35, SD = 1.05). The identified themes/patterns are narrated, sequenced, and interpreted using different perspectives. Findings indicated that there are no conceptual problems throughout, but there are weaknesses in the textbook, such as the problem of horizontal articulation with other subjects like physics. There is a need to address the imbalance on the cognitive objectives, and teachers focus on lecturing to cover the voluminous content. This requires due attention through the participatory approach model (PAM), including awareness creation to reduce migration and providing continuous short-term trainings for teachers as per set national and/or international standards at all levels to improve the quality of education.

**Keywords:** articulation; balance; cognitive complexities; constructivism; content analysis; continuity; integration; instructional practices; mathematics textbook; sequence

## 1. Introduction

As compared to other subjects and fields of study, mathematics is a fundamental subject of all sciences and technology since its applications spear in different areas [1]. Mathematics is one of the most important and compulsory subjects in the Ethiopian education system (curriculum) at all levels. Mathematics textbooks have significant impact on students' learning due to their role during the instructional processes in classrooms. In this regard, among the instruments of quality assurance mechanisms in education in general and mathematics in particular, critical content analysis by experts could be one possible approach, thereby identifying strengths and weaknesses to take corrective measures. As far as education is concerned, we have to have a clear understanding of the concepts of curriculum and its materials/packages. Curriculum is a blueprint for a whole level of education. According to Parmar [2], curriculum is defined as a mixture of the syllabus, course design, and schedule. It is offered for the entire year and established by the education board and instructors. On the other hand, according to MrHarrison [3], 'curriculum is, perhaps, best thought of as that set of planned activities which are designed to implement a particular educational aim—set of such aims—in terms of the content of what is to be taught and the knowledge, skills, and attitudes that are to be deliberately fostered together with statements of criteria for selection of content and choices in methods, materials, and evaluation'. In short, MrHarrison [3] defined curriculum as the overall content taught in an educational system or a course. The curriculum lasts till the completion of the course, and it embodies a syllabus, textbook, teacher's guide, assessment tools, and learning resources in it. The word syllabus originates from the Greek word "syllibos", which is defined as the outlet of a course of study [4]. A syllabus is a road map of a given subject that brings together what is taught, how it is taught, and why. It serves as a mother document for teachers to develop annual, unit, and daily lesson plans.

The main difference between a book and a textbook is that textbooks have a purely educational purpose, while books may have different purposes serving, for example, as reference materials. The definitions for textbooks are wide and varied. According to Russo [5], one common definition is that a textbook is a printed and bound artifact for each year or course of study. It contains facts and ideas around a certain subject. A textbook that is prepared in accordance with the syllabus has a set of chapters, question-answers, and exercises included in the curriculum to improve the learning standards of a student [5]. Similarly, a textbook is the basic instrument of teaching, and it is half of the apparatus of teaching. The textbook follows all of the essentials mentioned in both the curriculum and the syllabus for an academic semester or year. Textbooks are created by academic writers and publishers in accordance with the curriculum and syllabus [2]. On the other side, MrHarrison [3] defines a textbook as an embodiment of the syllabus and of all aspects of classroom practices. The textbook has been emphasized as the most important tool in the teaching-learning process of mathematics. It has been identified as one of the factors affecting students' learning outcomes [6].

## 1.1. Rationale and statement of the problem

In Ethiopia, there have been attempts to introduce initiatives and policy directives, including the 1994 training and education policy (ETP), which was aimed at addressing raised concerns regarding the quality of education [7]. In support of this, the Ministry of Education has developed numerous education sector reform programs and policy documents, including different education sector development programs (ESDP I, II, III, IV, V, and VI).

As stated by MOE [8], the challenges to secondary schooling include low capacity, low secondary school expansion rates, low transition rates, as well as general socio-economic and cultural barriers, natural disasters, conflict, and so forth, and hence demand for labor. In addition, the education sector development program (ESDP VI) of the Ministry of Education [8], where all recent educational goals emanate from, suggests the implementation of quality teacher professional development (TPD) that would produce passionate, motivated, qualified, professionally trained, and well-equipped teachers and educators for quality teaching. However, it became very clear that there is a deterioration in the quality of education in recent Tigray, Ethiopia. Some factors for this are the destructive war, which lasted about three years, and the COVID-19 pandemic. As far as the war is concerned; it resulted in a complete collapse of the whole education system in terms of a) infrastructure: it has become malfunctioned, that is, a considerable part of the education personnel including teachers and their students have displaced, migrated to Asia and Europe or victimized and also classrooms, plasma televisions, libraries, laboratories, and other educational facilities are completely destroyed, b) school databases have been completely destroyed, c) schools have become centers/camps for internally displaced people (IDP) and still continued, and d) all other resources such as school furniture, books, laboratory equipment and chemicals, water services, electricity and communication systems are completely destroyed or cut off. The outcome of the war is, then, a dramatic increase in the number of out-of-school teachers, students, and disadvantageous ones, including people with disabilities, in the region. In addition, schools of all levels in the region have been closed for three years. Therefore, the only choice left is to use the existing limited number of textbooks effectively and provide short-term on-the-job trainings to teachers so that they can be able to work in the challenging environment and try to compensate for the wasted time. In this regard, it would be very important to identify the gaps and major problems related to the available textbooks and teachers and then propose possible solutions for action by the concerned authorities.

## 1.2. Objectives of the study

The specific objectives of this research work are to:

- Conduct content analysis and identify the major problems and strengths associated with the Ethiopian mathematics textbook for grade-12.
- Investigate the implications of the organization of the textbook, philosophical and socio-cultural perspectives, and learning theories for teachers' instructional practices.
- Identify and analyze the factors affecting grade-12 mathematics teachers' instructional practices in selected schools of the Tigray region, Ethiopia.
- Recommend possible remedial actions and policy directions related to issues of textbook development and teacher training.

## 1.3. Research questions

Education is the most effective instrument for national development, and teachers are the executors and facilitators of education. Content analysis and revision on textbooks, as well as improving the qualifications and competence of teachers, are very important for improving the quality of education. Thus, this study tries to address the following research questions:

- What are the major problems and strengths associated with the Ethiopian mathematics textbook for grade-12?

- What are the implications of the organization of the textbook, philosophical and socio-cultural perspectives, and learning theories for teachers' instructional practices?
- What are the major factors affecting high school mathematics teachers' instructional practices in Tigray and how?
- What are the possible remedies for the identified challenges?

## 2. Literature review

### 2.1. What is content analysis of a textbook

It is accepted worldwide that mathematics and science textbooks have a major influence on classroom practice. The textbook is a tool, and the teacher must know not only how to use it but also how useful it can be. And the quality of a textbook matters on the quality of lesson presentations, in particular, and on the instructional practice in general.

Content analysis is a research tool used to determine the presence of certain words, themes, or concepts within some given qualitative data (e.g., text). Using content analysis, researchers can quantify and analyze the presence, meanings, and relationships of certain words, themes, or concepts. When a student textbook is well-written, it could lighten the burden of learning and teaching and enhance the achievement of students. For this purpose, contents need to be analyzed in a detailed manner so as to transfer relevance and clear information to the learners in the learners' world of work and to new situations.

Sunday [6] further addresses a textbook by stating that "Textbook as an instructional tool is unique among all other instructional media due to possession of certain characteristics. It is durable, permanent (not transient), portable, and independent of electricity or electronic device when in use. It appears to be the oldest of instructional media. Due to its age-long existence and availability, it is common among teachers and learners more than any other medium."

To this end, there are many reasons for analyzing mathematics textbooks.

The first, particularly in cultures in which textbook production is effectively deregulated, is that it is important to evaluate a textbook's content against curricular specifications. In such circumstances, where textbooks are intended to make the curriculum visible [9,10], teachers should have confidence that they address adequately the system's expected outcomes. Importantly, dependent on national context, the textbook is afforded different responsibilities with respect to what children are expected to learn, with differing consequences for the teachers who use them.

The second reason is that even if two textbooks are similarly adequate in their addressing of curricular expectations, they may do so in different ways. Topics and the subtopics within them may be sequenced differently, or topics may be given different emphases. Generic competences like problem solving may be privileged more in some books than in others, with some offering such tasks in a continuous chain of opportunity and others locating them at the different chapters' ends. In other words, in systems in which teachers have multiple choices with regard to the textbooks they use, comparing textbooks' approaches to mathematics is important.

The third reason concerns the importation of textbooks from one country to another. Over the last few years, publishers, particularly in countries with unregulated textbook markets, have imported textbooks from countries whose students have excelled on large-scale tests of achievement.

#### 2.1.1. The elements and uses of content analysis

Content analysis can help teachers plan activities to help students learn. A content analysis of student compositions, for example, might help teachers pinpoint grammatical or stylistic errors. A content analysis of mathematics assignments might reveal deficiencies in the ways students attempt to solve word problems. Surveys, interviews, podcasts, social media comments, online feedback, web conversations, etc. are some of the ways in which the data can be collected. The seven major elements that are considered for performing content analysis are: words, characters, themes, paragraphs, concepts, items, and semantics.

#### 2.1.2. Steps in content analysis

It is easy for the researcher to get diverted into various directions if he/she is not following step-by-step content analysis. By following a set of steps, researchers can effectively analyze a set of data to uncover information, identify trends, and draw meaningful conclusions. The content analysis process can be broken down into 5 steps.

Step 1: Identify and collect data.

There are numerous ways in which the data for qualitative content analysis can be collected. Both verbal and non-verbal methods can be used to collect the data from the participants of the study. Surveys, interviews, podcasts, social media comments, online feedback, web conversations, etc. are some of the ways in which the data can be collected.

The seven major elements that are considered for performing content analysis are words, characters, themes, paragraphs, concepts, items, and semantics.

It is very important to capture the relevant information needed for the content analysis so that there is enough data for the intended content analysis. Just like any other research, content analysis also involves sampling, just that it is not the people or the products; the sample here is the content itself. The sample should be big enough to represent the entire population. Make sure to consider the appropriate time period for extracting the sample.

Step 2: Determine coding categories.

Measurement of content in content analysis is based on structured observation, which is a systematic observation based on certain written rules. These rules detail how the content should be categorized. The categories defined for the analysis should be mutually exclusive. These written rules help to make replication easier and also to improve reliability. To be able to analyze the content, it is important to divide the entire content collected into categories so that it can be managed better. This is a process of selective reduction where the text is reduced to categories so that the research can be focused on the categories for specific words and patterns that answer the questions of the researcher. The categories or codes could be a word, a phrase, a sentence, an article, brand names, numbers, competitor names, countries, emotions, and much more.

Step 3: Code the content.

A code is a label that you assign to the text that has to be analyzed, and the text can be a word or a phrase. For example, the code 'politician' is assigned when there is a mention of any political person in the text. During the coding process, a number should be assigned to each category. The code should be mutually exclusive.

Coding is a set of rules that explain the method of observing the content in a given text. Coding will identify four important characteristics: frequency, direction, intensity, and space.

- Frequency describes the number of times a particular code occurs.
- Direction is the way in which the content appears: positive, negative, opposite, etc.
- Intensity denotes the amount of strength towards a particular direction.
- Space refers to the amount of space assigned to the text or the size of the message.

The list of words, phrases, images, videos, etc. is loaded to social media and other data sources to locate them in the source. Coding fetches highly reliable data as the word or phrase either exists or is absent.

Step 4: Check validity and reliability.

The next stage involves the testing of the codes that have been designed. The codes need to be validated for their reliability. The code has to be tested to check if it indeed measures what it purports to measure and to check if the results are consistent. Sampling validity refers to the examination and validation of the sample that was selected for the analysis. Semantic validity checks to see if the different phrases or words that are part of a category have a similar meaning and to make sure that they all belong to the same category. The correlation must also be checked to see if one measure can be substituted for another. A reliability check of the data is important to know if the data is reliable, which means that it should be constant throughout the measuring process. A reproducibility check is conducted by having numerous coders code sample data and compare the results. The data can also be checked for its stability, where a check is performed to assess the degree of content consistency over a period of time. An accuracy check should be performed to measure if the process conforms to the standard as expected and if it yields the results according to what it is designed for.

Step 5: Analyze and present results.

After completing the analysis, there will be several sets of information organized and available as files. This has to be presented in a report format that can be easily understood by the recipient. This involves a review of the final results, identifying patterns, arranging all the information in a sequence, and finally presenting it in the form of a report. The introductory sections of the report should address all basic information about the report, such as the period of the study, location chosen for the study, aim and objective of the study, explanation of different tools and techniques used during the study, and data sources and their composition.

The result's section should contain detailed information about the various factors that were observed during the study. It should be supported by data and presented in the form of graphs and matrices. A clear presentation of the information makes it easy for the reader to understand and interpret the report.

This section should be able to offer a detailed analysis and summary of observations that were gathered during the study. It should be a straightforward commentary on the observations during the study and should include the important findings and avoid the addition of too much information that can bury the actual findings.

The result's section should try to narrate the findings without too many judgments or solutions. This section should give direction to the important stakeholders for further discussions and evaluations of the situation and encourage them to make decisions based on the report.

**2.1.3. Content analysis in the Ethiopian Mathematics textbook**

The contents of Mathematics include number sense, measurement, geometry, patterns and algebra as well as statistics and probability. Numbers and number sense as a strand, for example, include concepts of numbers, properties, operations, estimations, and their applications. The recent Ethiopian grade twelve Mathematics textbook is of particular interest in the series of textbooks for preparatory mathematics education [11]. The textbook has 404 pages and is divided into 9 units: "Unit1—Sequences and series", "Unit2—Introduction to limits and continuity", "Unit3—Introduction to differential calculus", "Unit4—Applications of differential calculus", "Unit5—Introduction to integral calculus", "Unit6—Three-Dimensional geometry and vectors in space", "Unit7—Mathematical proofs", "Unit8—Further on statistics", and "Unit9—Mathematical applications for business and consumers" [11].

## 3. Methodology

The study has used mixed research approach as recommended by Creswell and Creswell [12] employing a critical content analysis of the mathematics textbook for grade-12 both by the candidates for doctor of education (DED) program and the instructor at Mekelle university integrating results obtained from a survey conducted on a sample of 23 teachers teaching grade-12 mathematics.

### 3.1. Data source

The data type collected were both quantitative and qualitative data. The sources of data for this study were both primary and secondary sources obtained mainly from content analysis of grade-12 mathematics textbook and from grade-12 mathematics teachers of randomly selected sample schools from three zones namely, Central, Eastern and Mekelle zones. out of a total of seven zones (since, the Ethiopian National School Leaving Examination at grade-12 is a requirement as an entry gate to the university programs). Also, other high-school textbooks such as physics are used as supporting materials to analyze whether or not there is a horizontal relationship between the subjects.

### 3.2. Data collection instruments

A critical review of textbook and other instruments including questionnaires consisting of closed-and open-ended items, focus group discussions with teachers, and observation on the overall school environment have been conducted. The use of multiple sources and multiple methods have helped to ensure reliability and validity of data.

### 3.3. Data collection process

For the purpose of data collection, candidates in the doctor of education (DED) program of the department, guided by their instructor, were assigned to critically analyze the contents of the mathematics textbook for grade-12. In addition, questionnaires were developed to collect data on the views of teachers teaching the grade level; interviews and focus group discussions were conducted with school principals/deputy principals and department heads; and overall observation of the school condition was done both by the instructor and the DED candidate.

### 3.4. Data analysis

The identified, organized themes and observed patterns obtained from the content analysis and responses from the teachers are narrated, sequenced, and interpreted using different perspectives and criteria. More specifically, all the chapters (units) and their sub-topics of the textbook have been analyzed in terms of coverage, their vertical and horizontal relationships, integration, and continuity of contents, as well as the application of the lower- and higher-level cognitive objectives. In addition, descriptive statistics such as frequencies, percentages, and measures of central tendency such as averages, standard deviations, and correlations are computed using Excel and used to interpret the data obtained from the survey.

## 4. Analysis of findings and discussion

### 4.1. Selected criteria for content analysis

According to Palma [13] and Thanavathi [14], in the process of content analysis, balance, articulation, sequence, scope, integration, and continuity of the chapters or units are critical elements used in organizing or putting together the different learning contents. Moreover, while preparing textbook contents, understanding and interpreting the levels of Bloom's taxonomy is very crucial [15]. Based on these criteria, critical analysis of grade-12 mathematics textbook will be taken place in the following sections.

#### 4.1.1. Balance

It is the way of giving an appropriate weight to each aspect of the design so that distortions do not occur [14]. Moreover, Palma [13] in the study of Bilbao supported that curriculum content should be fairly distributed in depth and breadth of the particular learning area or discipline to ensure the course or area is not overloaded. For this particular case, let us have a look at the data given in **Table 1** regarding the balance of the units of the grade twelve mathematics textbook. As can be observed from the distribution of **Table 1**, most of the units have an approximately balanced number of pages.

**Table 1.** Distribution of chapters by number of pages (balance) (Source: Ethiopian Mathematics Textbook for Grade 12 prepared by Ministry of Education).

| Unit number | Page ranges | Total number of pages |
|---|---|---|
| 1 | 1–40 | 40 |
| 2 | 41–102 | 62 |
| 3 | 103–160 | 58 |
| 4 | 161–206 | 45 |
| 5 | 207–270 | 63 |
| 6 | 271–295 | 24 |
| 7 | 296–321 | 25 |
| 8 | 322–369 | 47 |
| 9 | 370–393 | 23 |

However, the writers gave special attention (more focus) to units 2, 3, and 5 as compared to the other units. And less attention was given to units 6, 7, and 9. Detailed analysis indicated that most of the contents are appropriately balanced. However, there are some weaknesses in which the writers have to bear in mind. For example, the writers gave more emphasis to:

The sigma notation and partial sums of unit-1; derivatives of combinations and compositions of functions of unit-3; extreme values of functions of unit-4; vectors in space of unit-6; revision on logic of unit-7; measures of central tendency and variability (dispersion) of unit-8 and percent increase and percent decrease of unit-9 received more emphasis as compared to the other contents in each unit. On the other hand, less emphasis was given to derivatives of some functions of unit-3 and rate of change of unit-4. The inappropriate balance can affect the attitude of both students and teachers negatively towards the course in general.

#### 4.1.2. Articulation of contents

Articulation refers to the vertical and horizontal interrelatedness of various aspects of the curriculum [14]. When we say vertical articulation, it is the sequencing of contents from one grade level to another. That is to say, curriculum components occurring later in a program must be related to those occurring earlier [16]. On the other side, horizontal articulation refers to the association of elements of a program occurring simultaneously. Teamwork among the teachers will enhance articulation of contents in the curriculum [17]. The benefits of the horizontal dimensions are implementing real-life problem-solving of mathematics lessons integrating with other subjects and encouraging coordination of teachers from different fields for better student learning. Concerning this issue, there is vertical articulation of grade twelve mathematics with grades 9 and 11 mathematics. For instance, if we consider the contents in unit-1 (1.1: Sequence of functions), unit-2 (2.2: Limits of functions), and unit 3 (3.3: Derivatives of combinations and compositions of functions) of grade twelve mathematics, we have prerequisite concepts in unit-4 (4.2: Functions) of grade nine, units 1, 3, and 5 on polynomial, exponential, logarithmic, and trigonometric functions of grade-10, respectively, as well as unit-9 (further on trigonometric functions) of grade eleven mathematics (see **Table 2**).

**Table 2.** Connection/articulation between subtopics of mathematics among grades by unit.

| Grade 12 sub-units | Grade 9 sub-units | Grade 10 sub-units | Grade 11 sub-units |
|---|---|---|---|
| 1.1. Sequences of functions | 4.2. Functions | 1. Polynomial functions<br>2. Exponential and logarithmic functions | |
| 2.2. Limits of functions | 4.2. Functions | 1. Polynomial functions<br>2. Exponential and logarithmic functions<br>5. Trigonometric functions | |
| 3.3. Derivatives of functions | 4.2. Functions | 1. Polynomial functions<br>2. Exponential and logarithmic functions<br>5. Trigonometric functions | 9. Trigonometric functions |
| 6. Geometry and vectors in space | 7. Vectors in two dimensions | 4. Coordinate Geometry<br>6. Plane Geometry<br>7. Measurement | |
| 8. Statistics & probability | 6. Statistics & probability | | 5. Statistics & probability |

Moreover, the contents of grade twelve mathematics of unit-8 (further on statistics) have prerequisite concepts in grades nine and eleven of unit-6 and unit-5 (statistics and probability), respectively. On the other hand, the contents of unit-6 (three-dimensional geometry and vectors in space) of grade twelve mathematics are related with unit 7 (vectors in two dimensions) of grade nine and unit 7 (measurement) of grade ten mathematics (see **Table 2**).

Since the application of mathematics at this level is also very high in physics as compared to other subjects, it is useful to look into the nature of horizontal articulations between these subjects on some selected grade level.

Even though there are connections between units of grade-11 physics and grade-12 mathematics, physics teachers at grade 11 encounter bigger challenges while teaching physics of units 3, 4, and 5 (velocity, acceleration, force, and work done, respectively), which require the application of derivatives and integrals from mathematics, which are covered (offered) only in mathematics for grade 12 due to the absence of horizontal articulation (see **Table 3**).

**Table 3.** Connection between subtopics of mathematics and physics by unit and grade level.

| Grade 12 Mathematics unit/sub-topics | Grade 11 Physics sub-topics |
|---|---|
| 3. Derivatives | 3. Velocity |
| 4. Application of derivatives | 4. Acceleration |
| 5. Application of integration | 5. Force and work done |

#### 4.1.3. Sequence (arrangement) of units

This is the logical arrangement of the subject matter, or what is referred to as the vertical relationship among curricular areas [13]. Sequencing in curriculum is about determining the order of concepts within a grade level and subject. Moreover, the sequence can be defined as the focus on the order in which things occur [18]. On the other hand, sequence refers to the deepening and broadening of content as it advanced to the higher levels [17]. According to Orenstein and Hankins [16], sequence includes patterns like simple to complex learning, pre-requisite learning, whole to part learning, and chronological learning. Based on this criterion, most of the contents of grade 12 mathematics are arranged chronologically and have a good vertical relationship with the previous grade levels. To mention some, unit-2 (introduction to limits and continuity) is the prerequisite for unit-3 (introduction to differential calculus); unit-3 (introduction to differential calculus) is also a prerequisite to unit-4 (applications of differential calculus), and this is a prerequisite to unit-5 (introduction to integral calculus). Moreover, unit-7 (mathematical reasoning) of grade-12 has prerequisite concept in unit-4 (mathematical reasoning) of grade-11, and unit-6 (three-dimensional geometry and vectors in space) of grade 12 has prerequisite concept in unit-3 (coordinate geometry) of grade-11. Unit-8 (further on statistics) of grade 12 has prerequisite concepts in unit-5 (statistics and probability) of grade 11 and unit-5 (statistics and probability) of grade 9. However, as indicated in grade 11 of unit-9 (further on trigonometry), it is designed only for natural science students. But social science students are supposed to apply trigonometric concepts in grade-12 of unit-3 (derivatives of trigonometric functions) without having a clear understanding of the concept of trigonometric functions from previous grade levels. So, social science students might not understand how to differentiate trigonometric functions as the natural science students do.

#### 4.1.4. Integration of the units

It is the linking of all types of knowledge and experiences that are included in the curriculum plan [14]. Integration refers to combining two or more subjects when teaching a topic. When we say integrating the curriculum content, it is an effort at horizontal articulation [16]. According to postmodernism, constructionism, and poststructuralism, knowledge cannot be separated from its reality, people cannot disconnect themselves from their investigations, and the curriculum cannot exist as separate bits [16]. According to these criteria, there is an interlinking of the content of the subjects that are taught in a certain class. To mention a few, the contents in unit-4 (applications of differential calculus) and unit-5 (5.4: Applications of integral calculus) have more applications related to physics while evaluating the velocity, acceleration, and work done by an object. However, it needs some modification on the arrangement of horizontal articulation of mathematics and physics. Because the concepts of physics (velocity, acceleration, and work done) that need the concepts of mathematics (from grade 12) are placed in grade 11 before familiarizing mathematical concepts. Moreover, there is an interlinking of unit-1: applications of arithmetic and geometric progressions with free falling motion of physics; unit-6: three-dimensional geometry and vectors in space with vector quantities of physics; unit-9: mathematical applications for business and consumers with business and marketing.

#### 4.1.5. Continuity of the units

It is the vertical replication of continuous instruction to increase depth and breadth of knowledge [14]. This reinforces students’ learning by allowing them to practice skills they learned earlier and to consider old information in a new way. Bilbao et al. [17] defined continuity as the constant repetition, review, and reinforcement of learning. To this end, almost all the contents of grade-12 mathematics have good continuity with the previous grade levels or with this course. To mention some, the concepts of limit and continuity of functions (unit-2) are again practiced to learn the concept of derivatives of functions and their applications (unit-3 and unit-4).

Similarly, the concept of derivative of functions (unit-3) is applicable in teaching the concept of integration (unit-5). On the other side, unit-8 (further on statistics) is the continuity of unit-5 (statistics and probability) of grade-11 and unit-5 (statistics and probability) of grade 9. Unit-6 (three-dimensional geometry and vectors in space) is the continuity of unit-3 (coordinate geometry) of grade 11, and unit-7 (mathematical proof) is the continuity of unit-4 (mathematical reasoning) of grade 11. However, the concepts of sequence and series (unit-1) and the concepts of limit and continuity of functions (unit-2) are new concepts to this grade level, and they are very challenging to handle easily. This is because they do not have prerequisite concepts in this course or in the previous grade levels (see **Table 4**).

**Table 4.** Topics showing continuity by unit and grade levels.

| Contents of grade-12 by unit number | Continuity | Continuity by grade level |
|---|---|---|
| 3. Derivatives | Limits of continuity | Grade-10 &12 |
| 3. Application of derivatives | Derivatives | Grade-12 |
| 4. Integration | Derivatives | Grade-12 |
| 6. Geometry and vectors | Coordinate geometry | Grade-10 &11 |
| 7. Mathematical proof | Mathematical reasoning | Grade-11 |
| 8. Further on statistics and probability | Statistics and probability | Grades-9 & 11. |

## 4.2. Analysis on levels of cognitive complexities

While preparing textbook contents, understanding and interpreting the levels of Bloom's taxonomy is very crucial [15]. Although there is no bad or good classification in the taxonomy, the intended end is to attain the higher-levels of learning.

**Table 5.** Level (frequency) of using the cognitive taxonomies by unit number.

| Taxonomy | $U_1$ | $U_2$ | $U_3$ | $U_4$ | $U_5$ | $U_6$ | $U_7$ | $U_8$ | $U_9$ | Total | % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Remembering | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 4.88 |
| Comprehension | 2 | 2 | 0 | 0 | 1 | 3 | 3 | 2 | 0 | 13 | 31.7 |
| Applying | 5 | 3 | 3 | 4 | 4 | 1 | 2 | 1 | 3 | 26 | 63.42 |
| Analyzing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Synthesizing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Evaluation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total** | **7** | **5** | **5** | **4** | **5** | **4** | **5** | **3** | **3** | **41** | **100** |

Note: $U_i$ stands for units where $i$ = 1, 2, 3, …, 9.

The results displayed on **Table 5** show the distribution of unit objectives along the cognitive complexities ranging from remembering to evaluation. As can be seen from **Table 5**, most unit objectives are at the comprehension and application levels. The percentage coverage of objectives along the levels is: 4.88% for remembering, 31.7% for comprehension, 63.42% for applying, and the rest are neglected. Obviously, there is an imbalance of the educational objectives in terms of distribution with the cognitive complexities. Thus, it is important to look into the problem and address this imbalance as a result of similar critical revisions on the textbooks.

## 4.3. Teachers' socio-economic perspectives in their mathematics teaching

### 4.3.1. Basic demographic information of teachers

This subsection presents basic information concerning the grade-12 mathematics teacher respondents (*N* = 23 respondents).

These include, among others, respondents' sex, educational status (qualification), situation on short-term trainings, teaching experience, address by their zones, average age in years and standard deviation (SD), average class size by gender, as well as average weekly teaching load. From the summarized data collected from three zones (involving a total of eleven schools) presented in **Table 6**, the respondents are all male (that is, no female teacher is teaching grade-12 mathematics in the selected schools), 13 (56.52%) are MSc and 10 (43.48%) are BSc holders, 21 (91.30%) of them with teaching experience of more than ten years, and the average teaching load is 17.91 periods (contact hours) per week with an average class size of 58 students. The average age of the respondents is calculated to be 44.57 years.

**Table 6.** Demographic characteristics of grade-12 Mathematics teacher respondents.

| No | Observation points | Category | Frequency (value) | Percent | SD |
|---|---|---|---|---|---|
| 1 | Sex | Male (All) | 23 | 100 | |
| 2 | Qualification | BSc/Bed. | 10 | 43.48 | |
| | | MSc. | 13 | 56.52 | |
| 3 | Teaching experience | 5–7 years | 2 | 8.70 | |
| | | Above 10 years | 21 | 91.30 | |
| 4 | Average ag | | 44.57 yrs. | | 6.76 |
| 5 | Address (zone) | Central zone | 9 | 39.13 | |
| | | Eastern zone | 7 | 30.43 | |
| | | Mekelle zone | 7 | 30.43 | |
| 6 | Class size (Avg) | Male | 27.49 | | 7.06 |
| | | Female | 30.83 | | 7.17 |
| | | Total | 58.30 | | 11.00 |
| 7 | Av. Load/week | Total | 17.91 periods | | 4.81 |
| 8 | Short-term trainings | None | 16 | 69.57 | |
| | | Up to three times | 7 | 30.43 | |

The majority of the respondents, that is, 16 (69.57%), have said that they did not participate in any short-term training that can improve their profession. From the results, it can be seen that maturity, educational qualification, and teaching experience of the teachers may not be problems. Clearly, large class size (minimum of 58 students in a class), insufficient short-term professional training, and an uncomparable gender gap among mathematics teachers, where there are more female students than their counterpart males, are among the observed problems affecting instructional practices.

### 4.3.2. Additional challenges of grade-12 mathematics teachers

A significant number of high school mathematics teachers in general and those that are teaching grade-12 mathematics in particular (summarized as in **Table 7** and from responses to open-ended questions) confirmed that the major challenges, among others, they are facing are:

**Table 7.** Number of teacher respondents on factors affecting their instruction ($N$ = 23).

| Items | Mean | SD |
|---|---|---|
| Low interest of students | 4.22 | 1.06 |
| Bulky content | 4.00 | 1.14 |
| Lack of support from parents | 3.78 | 0.98 |
| Insufficient periods (time) | 3.65 | 1.05 |
| Insufficient training for teachers | 3.35 | 1.05 |
| Shortage of teaching aids | 3.17 | 1.17 |
| High work load for students | 3.09 | 0.97 |

Note: Strongly agree = 5, agree = 4, neutral = 3, disagree = 2, strongly disagree = 1.

1) The bulky content of the textbook and the forced accelerated approach to cover the huge volume to compensate for the time wasted during the destructive war in the region (Tigray), 2) low interest of students towards the subject and hence deteriorating trend to attend classes, 3) critical economic problem of teachers (low living standard) that is negatively affecting teachers commitment to their teaching profession; 4) insufficient short-term training for teachers; 5) inconvenient school environment due to the fact that school compounds, buildings, and their classrooms are still serving as internally displaced people (IDP) centers (camps) and, at the same time, as teaching classrooms (e.g., Adi-Haqi and Hawelti comprehensive secondary schools at the capital Mekelle, Finote-Berhan comprehensive school at Adigrat, the center of the Eastern zone, Nigiste-Saba preparatory school, and Axum preparatory schools at Adwa and Axum towns, respectively, in the Central zone), 6) lack of continuous support from parents, 7) shortage of teaching aids, 8) additional work load for students, and 9) imbalance on the use of cognitive objectives (that is, most mathematics activities in the textbook focus on lower-level cognitive objectives).

In addition, beyond the problems of conceptual understanding that are observed on a number of high school students with regard to mathematical concepts, there are also observed misconceptions on some teachers both on cognitive or intellectual values and methodological approaches in their teaching.

In general, these multidimensional problems are some of the major findings that affected the smooth instructional practices of teachers and hence the quality of education in the region and the country as a whole (see **Table 7**). This in turn leads to low achievement of students and hopelessness in their educational career. As a result of these negative influences, a huge number of young male and female high school students, including some young teachers, are dropping out of schools and fleeing the country, becoming migrants to Arab and European countries. Thus, there is a need to pay due attention and integrate approaches among stakeholders to solve the problems strategically. Again, by conducting continuous on-the-job short-term trainings, there is also a possibility to develop the power of thinking and reasoning in terms of incorporating different methods (e.g., inductive and deductive approaches, problem-solving, project work, etc.), analysis, generalization, and judgement of teachers. For example, consider the formula given by:

$(1 + 2 + 3 + \ldots. + n)^2 = 1^3 + 2^3 + 3^3 + \ldots + n^3$ for the first $n$-natural numbers. That is, for the first $n$-natural numbers, the square of the sum and the sum of their cubes are equal.

Many students and some teachers wrongly convince themselves that this equation involving different exponents cannot be true because they wrongly think that

$(1 + 2 + 3 + \ldots. + n)^2 = 1^2 + 2^2 + 3^2 + \ldots + n^2$. But it is possible to apply the induction method to show the equality rather than simply memorizing the formula. Of course, one can observe that it holds true for $n = 1, 2, \ldots, k$. So, we want to show that it also holds true for $n = k + 1$. That is, consider $\{1 + 2 + 3 + \ldots. + k + (k + 1)\}^2$ and sum ($i^3$, for $i = 1, 2, 3, \ldots, k, k + 1$) = sum ($i^3$, for $i = 1, 2, 3, \ldots, k$) + $(k + 1)^3$.

Using the Gauss formula for $1 + 2 + 3+ \ldots. + k + (k + 1) = \{(k + 1)(k + 2)\}/2$ and the initial hypothesis, the two expressions, respectively, are the same as $\{(k + 1)(k + 2)/2\}^2$ and $\{k(k + 1)/2\}^2 + (k + 1)^3$.Simplifying both expressions, we have the same result given by $\{(k + 1)^2(k + 2)^2\}/4$ and hence it is proved by applying the induction method.

### 4.3.3. Application of teachers' teaching strategies in mathematics

Most of the information indicated that there is no encouraging condition to apply student-centered approach because teachers are required to use the accelerated teaching approach, and hence, they are rushing to cover the textbook contents. So mostly, the teaching methods are lecture-focused, as can be seen from the data presented in **Table 8**. That is, the teaching approach becomes teacher-dominated with insignificant students' participation.

**Table 8.** Summarized data on teacher respondents to their teaching strategy ($N = 23$).

| Items (methods) | Mean | SD |
|---|---|---|
| Oral Q-A approach | 3.78 | 1.02 |
| Home-work | 3.74 | 0.74 |
| Doing on assignments | 3.04 | 0.62 |
| Independent class work | 2.78 | 0.59 |
| Problem-solving (open-ended) | 2.78 | 0.93 |
| Group discussion | 2.48 | 0.88 |
| Individual presentation by students | 2.17 | 0.70 |

Note: Always = 5, most of the time = 4, some-times = 3, very rarely = 2, not at all = 1.

The respondents have said that most teachers apply the lecture method, and they focus on the simple question-and-answer approach (Mean = 3.78, SD = 1.02), giving homework (Mean = 3.74, SD = 0.74), assignments (Mean = 3.04, SD = 0.62), with relatively little attention for group work (Mean = 2.48, SD = 0.88), and students' individual presentations (Mean = 2.17, SD = 0.70).

Even though the differences on the results for responses seem to be insignificant, as can be observed from **Table 9**, the instructional constraints (challenges) and the selected teaching methods applied are pair-wise uncorrelated (the value of $r$ is close to zero) or negatively correlated (that is, there are disagreements between the responses for the problems and the frequent use of the teaching strategies). So, the linear relationships to responses between the selected problems (listed on the left extreme column) and the teaching strategies (listed on the top row) of **Table 9** are generally weak except that relatively stronger negative correlations are observed between shortage of time versus individual student presentation ($r = -0.5099$), low student interest, and insufficient training for teachers versus implementing group work/discussion methods with $r = -0.4847$ and $r = -0.4700$, respectively, indicating the level of disagreements on the views of respondents.

**Table 9.** Correlations ($r$) between responses of pairs of different variables ($N = 23$).

| Variables | Q-A approach | Problem solving | Group work | Student presentation | Homework |
|---|---|---|---|---|---|
| Huge content | −0. 2613 | 0.0418 | −0.3209 | −0.0079 | −0.0176 |
| Low student interest | −0.1793 | 0.0038 | −0.4847 | 0.0661 | 0.1841 |
| Insufficient training | −0.1818 | 0.0330 | −0.4700 | −0.3785 | 0.1743 |
| Shortage of time | −0.0364 | −0.0330 | −0.2919 | −0.5099 | −0.2873 |

#### 4.3.4. Application of teachers' assessment methods in Mathematics

Due to the overall instructional processes, formative and continuous assessment techniques are almost impractical in the classroom. Hence, teachers in almost all schools focus on summative assessment methods as summarized in **Table 10**.

**Table 10.** Summarized data on responses of teachers to their assessment methods ($N = 23$).

| Items (strategies) | Mean | SD |
|---|---|---|
| Multiple choice items | 3.78 | 0.78 |
| True or False tests | 3.09 | 1.02 |
| Provide feed-back to students | 2.87 | 1.03 |
| Self-evaluation activities | 2.59 | 0.88 |
| Short Matching tests | 2.39 | 0.97 |
| Peer-evaluation activities | 2.30 | 0.95 |
| Port-folio organization | 1.74 | 0.90 |
| Using parents' feed-back | 1.70 | 0.69 |

Note: Always = 5, most of the time = 4, some-times = 3, very rarely = 2, not at all = 1.

The results displayed in **Table 10** show that most respondents confirm that the assessment methods mostly applied are: multiple choice items (Mean = 3.78, SD = 0.78), true or false items (Mean = 3.09, SD = 1.02), providing feedback to students (Mean = 2.87, SD = 1.03), and self-evaluation (Mean = 2.59, SD = 0.88). On the other hand, the assessment methods that are least applied by teachers include the use of parents' feedback (Mean = 1.70, SD = 0.69), organizing portfolios (Mean = 1.74, SD = 0.90), and peer evaluation (Mean = 2.30, SD = 0.95). From this, it can be concluded that teachers focus on short, objective types of assessment methods.

## 5. Conclusion and recommendations

The recent grade twelve mathematics textbook is of particular interest in the series of textbooks for preparatory mathematics education. The textbook has 404 pages and is divided into 9 units. The purpose of this content analysis supported by school teachers' responses is quite important to transfer relevant and clear information to the concerned authorities and to lighten the burden of teaching and learning. As a summary, in the process of content analysis of textbooks in particular and the development/review of curriculum and textbooks in general, the involvement of different professionals and stakeholders is important at all levels, as displayed in **Figure 1** for the participatory approach model (PAM), which is proposed from the data in this study.

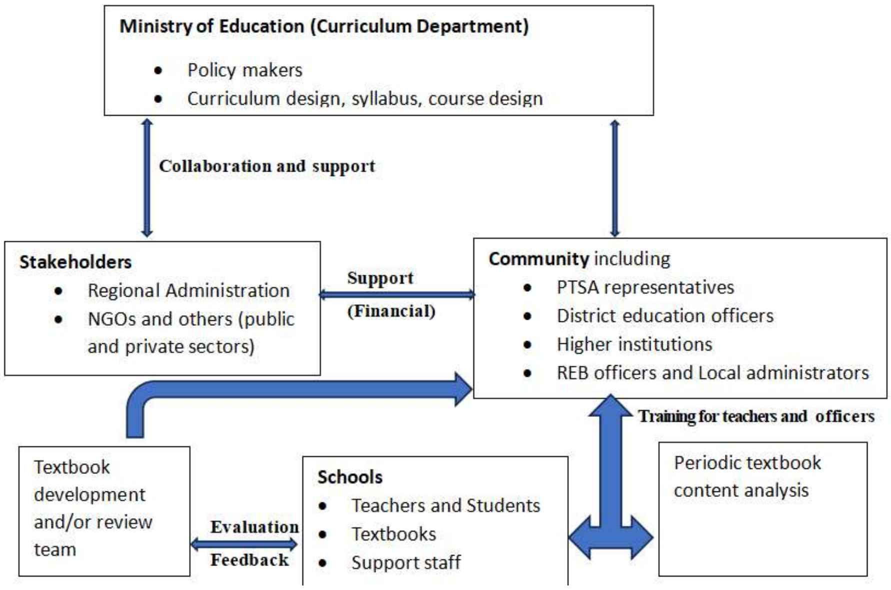


**Figure 1.** Participatory approach model (PAM) in textbook development, content analysis and review process.

The figure displays the importance of involving different individuals (teachers, students, parent-teacher-student associations, or PTSA representatives, and other experts) and governmental offices and/or non-governmental organizations (NGOs) during textbook development, content analysis, and review processes.

Specifically, the criteria selected to make the content analyses of this textbook were: balance, articulation, sequence, integration, continuity, and levels of cognitive complexities. After the content analysis, survey and focus group discussions with teachers have been made, and responses to closed- and open-ended items have been analyzed. Some important results have been obtained as concluding remarks, and hence the following recommendations are forwarded.

## 5.1. Conclusion

In general, there are no observed conceptual problems throughout the textbook, which shows the strength of the writers in terms of content knowledge and experience in the area. Most of the unit and sub-unit contents have good balance and are well organized in terms of providing examples, exercises for each sub-unit, and review exercises at the end of every unit. However, the writer(s) of the textbook gave special attention to unit-2, unit-3 and unit-5 as compared to the other units. And relatively less attention was given to unit-6, unit-7 and unit-9. Moreover, when we come to unit contents, it can be observed that more emphasis is given to the sigma notation and partial sums; derivatives of combinations and compositions of functions; extreme values of functions; vectors in space; revision on logic; measures of central tendency and measures of variability; and percent increase and percent decrease. On the other hand, less emphasis is given to derivatives of some functions and rate of change. Coming to articulation, there is a good vertical articulation of grade twelve mathematics, especially with grades 9 and 11 mathematics contents. However, there are some weaknesses in the horizontal articulation of grade 12 mathematics with grade 12 physics. Furthermore, most of the contents of grade 12 mathematics have good sequence with the previous grade levels. But grade 12 mathematics for social science students are supposed to apply trigonometric concepts in unit-3 (derivatives of trigonometric functions) without having any understanding about the concept of trigonometric functions from previous grade levels due to the absence of sequence of contents with grade 11 mathematics. As far as integration is concerned, it needs some modification on the arrangement of horizontal articulation of mathematics and physics. Because the concepts of physics (velocity, acceleration, and work done) that need the concepts grade-12 mathematics are wrongly placed in grade 11. Almost all the contents of grade 12 mathematics have good continuity with the previous grade levels or with this course. However, the concepts of sequence and series (unit-1) and the concepts of limit and continuity of functions (unit-2) are new concepts to this grade level, and hence students do not have prerequisite concepts in this course or in the previous grade levels. Concerning the levels of cognitive complexities, there is an imbalance of the educational objectives in terms of distribution, that is, most of the units focus on the lower-level educational objectives. With regard to teachers' responses, instructional practices focus on teacher dominated strategies. In particular, calculations of the 23 respondents revealed that the question-answer approach (Mean = 3.78, SD = 1.02) and giving home works (Mean = 3.74, SD = 0.74) are mostly applied teaching strategies. On the other hand, individual presentations by students (Mean = 2.17, SD = 0.70) and group work/discussion (Mean = 2.48, SD = 0.88) are among the least implemented strategies. Regarding assessment methods, multiple choice (Mean = 3.78, SD = 0.78) and true or false items (Mean = 3.09, SD = 1.02) are frequently applied, while the use of parents' feedback (Mean = 1.70, SD = 0.69), portfolio organization (Mean = 1.74, SD = 0.90) and peer evaluation method (Mean = 2.30, SD = 0.95) are the least practiced assessment methods.

In conclusion, it is found that the voluminous nature of the text book discourages teachers and students. Also, even those teachers that are on duty and students are traumatized due to the destructive war, almost all in economic crisis—as a result, most are being initiated for migration and highly in need of short-term trainings for psychological and professional developments.

### 5.2. Recommendation

From the detailed analysis, with all its strengths of the grade-12 mathematics textbook, it is observed that there are some weaknesses, such as the problem of horizontal articulation with other subjects like physics. In addition, it is indicated that there is a need to address the imbalance on the cognitive objectives, and this requires special attention at all levels (including at the national level) as a result of similar critical and detailed revisions on the textbook. In general, from the findings of this study, the following may be put as recommendations:

1) Syllabus and textbook development must consider the balance between the cognitive objectives and need to be participatory by engaging teachers, students' and parents' representatives, district/zonal/regional experts, universities, teacher training colleges, and other stakeholders, including governmental and non-governmental organization representatives.
2) Even if an excellent textbook is prepared, it would be useless without an excellent implementer. So, as the trainings provided to teachers so far are found to be insufficient, the implementation of continuous short-term training programs can be considered as one of the important interventions to alleviate problems associated with teachers' instructional practices. Thus, teachers at all levels need to be continuously trained through short-term refresher courses.
3) Even though identifying misconceptions and taking corrective measures is significantly important, at least in reducing the difficulties, nothing is addressed in the textbook as a solution for this issue. So, it must consciously be addressed.
4) For the benefit of the young generation and hence the whole society, there is a need to strategically engage in awareness creation programs involving all concerned stakeholders, including parents (see **Figure 1**). Such long-lasting programs can help to divert the migration sentiment of the young generation and focus on their future education-based endeavors.
5) The authors, editors, and publishers of textbooks in general need to be trained to follow a set national and/or international standard. In addition, the textbook contents as well as its physical appearance should be attractive to arouse students' interest.
6) Experience sharing from other countries could be helpful in developing teaching materials such as syllabi and curricula, textbooks, teachers' guides, and other reference books.

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