

# Comparative Analysis of Mathematical Knowledge in Physics Textbooks

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**Abstract** When different disciplines that physics lesson is related are examined, it is seen that mathematics becomes prominent as one of the most used fields. Physics textbooks are the most significant resources to clarify this relationship. Therefore, in this study, it is aimed to analyze the involvement of mathematical knowledge in physics textbooks used during 2011-2012 and 2016-2017 academic year in Turkey and to evaluate them according to mathematics subject distribution. In line with this aim, 9<sup>th</sup>, 10<sup>th</sup>, 11<sup>th</sup>, and 12<sup>th</sup>-grade textbooks used in physics lessons during 2011-2012 and 2016-2017 academic years are examined through document analysis method. According to the research results, it is found that mathematical knowledge is mostly located in Force and Movement chapters in both physics textbooks belonging to two different years. The involvement of mathematical knowledge in the chapters can result from the fact that Force and Movement chapters are the most suitable chapters for daily practices of mathematics. Besides, it occurs that the most used mathematical knowledge is the category of numbers and operations. This is because of the fact that basic level knowledge is used more because all mathematical knowledge is based on numbers and four operations. In this respect, that mathematical knowledge involved in physics textbooks is very excessive stands as the most significant evidence for that there is a strong connection between physics and mathematics.

**Keywords** Physics Textbooks, Mathematical Knowledge, Force and Movement, Basic Level Knowledge, Physics and Mathematics

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## 1. Introduction

The textbook is an indispensable tool and of generalized use in the classes of sciences [1]. In high school and university the textbooks mark the guideline to continuing in the activities of education [2]. There are diverse

variables that influence the learning from the textbooks and one of them relates to the content of the text and its organization [3, 4]. The authors of textbooks structure the contents in such a way that before presenting a new topic it is necessary introduce the concepts associated with the topic [5].

Therefore, solving ability regarding complex and interdependent problems belonging to different disciplines and individuals face in their daily lives should be taught in educational institutions [6]. Thus, both learning knowledge and skills regarding a specific discipline and creating synthesis by combining these with different subjects and fields can be obtained [7]. By considering such contributions, it can be thought that two of the most important and interrelated areas in educational institutions are physical sciences and mathematical knowledge used in physics lessons, correspondingly [8, 9]. Thus creating a synthesis by combining knowledge used by reasoning in mathematics and natural law in physics will be possible [10]. Additionally, transferring mathematical knowledge into practice through physics lessons can be obtainable [11].

These application fields may include different examples for mathematical knowledge partaking in physics lesson. For example, mathematical physics, quantum mechanics, physics laws, and problems regarding these within the discipline of physics show that physics is mostly related with the discipline of mathematics [10, 12, and 13]. In physics, a great deal of mathematical knowledge, which is from add-subtract operations which are the simplest mathematical operations to divergence, differential calculation, and the Dirac delta-function which require the most complex knowledge, is used. Therefore, a competent physician is expected to be a competent mathematician. For instance, scientists such as Kepler, Galileo, and Newton were very good at physics and mathematics [14, 15, and 16]. However, the situation can be reversed for students, unfortunately. Students are able to apply very little of their mathematical knowledge to physics lessons, and very few can feel adequate in the same field [17].

However, mathematics has a particular role in physics education. The most important connection between two disciplines is solving problems in physics lessons by using math [18]. Mathematical knowledge used in science classes contributes students regarding interrelating two lessons, doing practices in these fields, noticing the relationships between concepts used in different lessons, understanding abstract concepts easily and developing various cognitive skills [19]. The most important evidence of this situation is the fact that success in physics lesson is parallel with success in mathematics lesson [20, 21]. When such contributions are considered regarding both lessons, it is seen that mathematical knowledge included in physics classes should be presented according to suitable education levels of students.

Studies on the relations between physics and mathematics disciplines can be reviewed in two categories, generally. The first one is mathematical knowledge used in a specific subject of the physics lesson. When this knowledge is examined, it is seen that generally graphic analysis and interpretation ability [12, 17, 22, 23, 24], partly the concept of function [25], algebra [26], and ratio and proportion subjects [27] are concentrated. However, physical science does not only focus on mathematical knowledge in graphic analysis and interpretation, ratio and proportion or functions subjects. Along with presenting all mathematics subjects which physical science is related in physics lessons taught in schools, studies on two branches to be carried out together will vary. Therefore, there is a need to reveal mathematical knowledge use in physics lessons at different levels. The most important resources to determine this knowledge is curriculums and textbooks which are the helpers in the application of these curriculums. Thus, mathematical knowledge which is used in these textbooks is needed to be presented by examining textbooks.

Secondly, some studies evaluate mathematical knowledge used in physics and science classes in a general framework [9, 13, 28, 29, 30, and 31]. In these studies, generally, problems in physics lessons based on mathematics or attitudes and successes in both lessons are examined. Besides, these deficiencies from teacher's or student's perspective are evaluated at available studies [9, 13, and 28]. However, in addition to taking advantage of the knowledge of students or teachers, it is necessary to identify what kind of mathematical knowledge is needed in the physics subjects included in the program. Thus, the mathematical knowledge required by the program will be determined and it will reveal what kind of mathematical knowledge is needed. Since the textbooks are the most important practice resource in the current program, textbooks are expected to provide critical information to the researchers in this regard.

The essential resource that teachers can access from the first hand in situations such as planning or conducting a

course is textbooks. Through the textbooks, the current curriculum is reached at first hand [32]. Besides, teachers complete the points they think they are incomplete about the curriculum or the expression of a chapter with the help of textbooks. Textbooks are the main help in terms of presenting the objective of the course, doing practices on the subject, using education strategies, and practicing with homework included in books [32]. In the choice of resources for the course, preparation of textbooks in the direction of curriculum seems important [32, 33]. In addition, textbooks are important in terms of bringing information on many different sources together in terms of lecturing, sample problem solving and exercises. It is crucial to examine the resources that teachers use in every field in terms of different variables. In this context, many studies have been carried out on textbooks. When studies on physics textbooks are examined, it is found that these studies generally focus on subjects such as imagery evaluation, content-program adaptation [34, 35, 36]. However, when the function of textbooks is considered, studies on different fields are needed to be carried out. One of these fields is mathematical knowledge included in physics textbooks. The not encountering of any research on mathematical knowledge, which is very important in terms of physics, can be seen as a sign of an important deficiency in this area.

Recently, updating and renovation are often carried out in physics curriculum and textbooks, correspondingly in Turkey [37]. When the evaluation studies carried out in the physics curriculum, and accordingly the textbooks are examined, no studies done out of changing subject distributions according to grades and subject headings in renovation works carried out until 2007 [38]. In 2007, a new physics curriculum was developed and as a result, physics textbooks were gradually developed and applied in accordance with the new program starting from the 2008-2009 academic year. In 2013, a renewal study was carried out in the curricula, and the textbooks were gradually renewed to begin in the same year. It is important to show what innovations will be brought by these innovations and updates to the field. However, when studies on renewed textbooks are examined, more evaluation is made on the curriculum and its targets [37, 38, 39, 40], and there are no studies on mathematical knowledge and the use of mathematics. As stated in the examined literature, there is a significant deficiency regarding the examination of physics textbooks in terms of mathematical knowledge. Studies on mathematical knowledge in textbooks will be an important resource for both future textbooks to be updated or renewed, as well as studies on the link between physics and mathematics. Besides, it will have significant contributions on the studies about interactions between other fields such as mathematics, chemistry, and biology. Therefore, the main focus is the comparison of mathematical knowledge in

physics textbooks used in 2011-2012 and 2016-2017 academic years in Turkey, along with the distribution of this information. In this respect, answers are tried to find for two sub-problems;

1. How is the distribution of mathematical knowledge in physics textbooks of the two different years according to physics chapters?
2. How is the distribution of mathematical knowledge in the physics textbooks of the two different years according to the mathematics subjects?

## 2. Materials and Method

### 2.1. Research Model

The root of this study is based on qualitative research. The qualitative research approach includes data collection methods such as observation, interview, and document analysis and is defined as a method that deals with events and phenomena in a qualitative process based on these data collection tools [41].

In the study, document analysis which is the basis of qualitative research is used. Document analysis is used to reach sources in the direction of the study and determine data to be acquired [42]. Additionally, it includes the analysis of written and printed documents with respect to subjects to be carried out [43]. Document analysis is also categorized into two as the general survey and content analysis [44]. In content analysis, printed and visual materials are examined thematically and by specific categories. Therefore, the method of the study relies on content analysis within the context of document analysis that is based on qualitative research.

In this respect, the evaluated versions are 9<sup>th</sup>, 10<sup>th</sup>, 11<sup>th</sup>, and 12<sup>th</sup>-grade physics textbooks published by the Ministry of Education in Turkey for 2011-2012 academic year, along with 9<sup>th</sup> - 10<sup>th</sup>-grade physics textbooks printed by Tuna publishing and 11<sup>th</sup> -12<sup>th</sup>-grade physics textbooks printed by Dikey publishing, which are used during 2016-2017 academic year.

### 2.2. Data Analysis of Document Analysis

Since mathematics is included in physics lessons at every level of secondary education, it is decided to examine physics textbooks regarding all education levels. In this direction, the mathematical knowledge included in the contents of the 9<sup>th</sup>, 10<sup>th</sup>, 11<sup>th</sup>, and 12<sup>th</sup>-grade physics textbooks belonging to two different years are evaluated. Therefore, basic mathematics subjects are taken into consideration in data analysis. The data is analyzed in two steps. First, physics textbooks are analyzed according to mathematical knowledge. The evaluation is upon the mathematics categories to which mathematical knowledge

are related. In the second step, during the analysis of the physics textbooks, the places of mathematical knowledge within the physics chapters were analyzed. Then the mathematical knowledge included in the textbooks is modulated for both situations. This information has been transformed into two separate tables. Two mathematics teachers assisted the classification of mathematical knowledge, and they were required to make a classification in the mathematical subjects determined. Mathematic teachers gathered all mathematics subjects under six categories as Numbers and Functions, Algebra, Graphics, Transformation Geometry, Geometrical Concepts, Right Triangle, and Trigonometry. The category of Numbers and Functions contains the basic subjects regarding basic mathematical operations or basic subjects of numbers, which are used in the solutions of physics problems. The concepts of Root Numbers, Rational Numbers, Exponential Numbers, Repeating Numbers, Approximate Value, Four Operations, Vector Operation, Summation Symbol, Percentage, Chapter Conversion, Absolute Value, Arithmetic Mean, and Harmonic Mean are placed in the Numbers and Operations category. The category of Algebra includes advanced level operations which require equation solution and problem-solving instead of basic arithmetic operations. Equation Solving, Simple Inequality, Speed Problems, Rate and Proportion, Derivative, and Factorization are placed in the Algebra category. The Graphics category includes graphics analyze a given graphic or interpret the information. Subjects needed to use information regarding Symmetry, Reflexion, Recurrence, and Coordinate System is addressed within the context of Geometric Transformations. The category of Geometric Concepts includes basic concepts regarding the field of geometry. Geometrical Figure, Center, Barycenter, Triangle Similarity, Equilateral Triangle, Parallel and Vertical line, Circle, Sphere, Complementary Angle, Supplementary Angle, the Interior Angles of Triangle, Field-Cubage measurement, Surface Area, Steepness are taken into consideration in this category. The category of Right Triangle and Trigonometry contains geometrical information needed for physics subjects and problems in which trigonometry is necessary. The concepts of Right Triangle, Trigonometry, Trigonometric Ratios, Pythagoras Theorem, Trigonometric Expansions, Slope, Period and Information regarding these concepts are gathered under this category.

Physics chapters are grouped within themselves and placed in common categories. The Nature of Physics category includes physical science chapters from 9<sup>th</sup> and 12<sup>th</sup>-grades in the old version (Physics textbooks used in 2011- 2012 academic year) and Introduction to science of physics chapters from 9<sup>th</sup>-grades in the new version (Physics textbooks used in 2015- 2016 academic year). The category of Matter and its Properties consists of the Substance and Properties chapters from the 9<sup>th</sup>, 10<sup>th</sup>, 11<sup>th</sup> and 12<sup>th</sup>-grades in the old books, and also of Matter and its

Properties, heat and temperature from 9<sup>th</sup>-grade along with chapters of Pressure and Buoyancy from 10<sup>th</sup> grade in the new books. The Energy chapters, which are from the old and new books of 9<sup>th</sup> grade, are collected within the energy category. The force and motion category in the new books includes Force and Motion chapters from 9<sup>th</sup> and 10<sup>th</sup>, 11<sup>th</sup> and 12<sup>th</sup>-grades in the old books, along with chapters of Force and Motion from 9<sup>th</sup> and 11<sup>th</sup>-grades, and of Regular circular motion and Harmonic Motion from 12<sup>th</sup> grade. Electricity and magnetism categories in old books are composed of 10<sup>th</sup>-grade chapter of Electricity, from 11<sup>th</sup> grade chapter of Magnetism and 12<sup>th</sup>-grade chapters of Electricity and Electronic. The new books of 10<sup>th</sup> and 11<sup>th</sup>-grader also included Electricity and Magnetism chapters. The wave category was placed under the titles of Waves in all textbooks. The modern physics category in the old books is composed of the chapters of Modern Physics from 11<sup>th</sup> and 12<sup>th</sup>-grades, and also From Atoms to Quarks chapter from 12<sup>th</sup>-grade. It also includes the chapters of Atom Physics, Modern Physic, and Technological

Applications of Modern Physic in 12<sup>th</sup>-grade. The optic category is placed only in the new books for 10<sup>th</sup>-grades and is titled as optics chapter.

### 3. Results

In this section, as a result of examining 9<sup>th</sup>, 10<sup>th</sup>, 11<sup>th</sup> and 12<sup>th</sup> grades physics textbooks used in 2011-2012 and 2016-2017 academic years, mathematical knowledge in the books will be presented and comparisons will be made regarding the distribution of this information according to grade levels.

#### 3.1. Distribution of Mathematical Knowledge in Physics Textbooks by Physics Chapters

The distribution of the mathematical knowledge given in the categories according to the class levels as a result of the observation made according to the categories is given in Table 1 below.

**Table 1.** Distribution of mathematical knowledge in physics textbooks by physics chapters

Categories	9. grade		10. grade		11. grade		12. grade		Total	
	O	N	O	N	O	N	O	N	O	N
Introduction to Science	6	7	-	-	-	-	2	-	8	7
Matter and its Properties	17	67	12	28	29	-	18	-	76	95
Energy	3	39	-	-	-	-	-	-	3	39
Force and Motion	23	58	102	-	95	254	28	104	248	416
Electricity and Magnetism	-	-	31	36	35	147	5	-	71	183
Waves	8	-	19	25	-	-	65	9	92	34
Modern Physics	-	-	-	-	49	-	19	73	68	73
Stars to Quasars	-	-	-	-	29	-	-	-	29	-
Optic	-	-	-	52	-	-	-	-	-	52

O: Textbooks used in 2011- 2012 academic year

N: Textbooks used in 2015- 2016 academic year

As seen in Table 1, when the extent of mathematical knowledge in the physics textbooks is examined, it is seen that most are included in the chapter of Force and Motion at both two different academic years. When the same chapters are compared about mathematical knowledge in two different textbooks, the same chapter covered two times more in the new textbook compared to the old one. This chapter is not only included in the 10<sup>th</sup>-grade in new textbooks, but it is so in all textbooks of other grade levels. When it is looked from the mathematical knowledge perspective, it is seen that the most mathematical knowledge in all books is placed within the same chapter of 11<sup>th</sup>-grade textbook with 254 points. When only the mathematical knowledge of old books is evaluated, the most mathematical knowledge seems to be in the 10<sup>th</sup>-grade textbooks belonging to the same chapter.

This chapter, in the new textbooks, is followed by Electricity and Magnetism chapter in terms of mathematical knowledge while in the old versions it is followed by the wave's chapter. While in the old versions the chapter was absent only in the 9<sup>th</sup>-grade books, in the new textbooks it is absent in both 9<sup>th</sup> and 12<sup>th</sup>-grade textbooks. However, when evaluated in terms of total mathematical knowledge, it contains much more information than the old versions. The same chapter, in the new textbooks for 10<sup>th</sup>-grades, contains 147 pieces of mathematical knowledge, which is the second most after the Force and Motion chapter.

The matter and its properties chapter used to place in the books for all four grades, now it is only in books for 9<sup>th</sup> and 10<sup>th</sup>-grades. Despite this; however, the mathematical knowledge contained in the new versions of the same chapter is more than the old books. The modern physics chapter is in books for 11<sup>th</sup> and 12<sup>th</sup>-grades. The chapter is covered about the same amount in old and new versions. The wave's chapters were included in books for all four grades in old versions,

however it is now placed in the books for 10<sup>th</sup> and 12<sup>th</sup>-grades. Although the chapter was included in books for 11<sup>th</sup> in the case of old versions, no mathematical knowledge was used in this chapter. Only this chapter within the old version of books contains more mathematical knowledge when compared to the new version. When the situation is evaluated for grades on a case by case basis, the same chapter is covered with 8 pieces of mathematical knowledge in old books for 9<sup>th</sup>-grade, and nine parts of mathematical knowledge in new books for 12<sup>th</sup>-grade, which makes the chapter among the chapters in which the least mathematical knowledge has been used.

The Introduction to Science of Physics chapter has a very low level both in terms of mathematical knowledge and the rate of coverage at grade levels. The chapter was included in old versions for 9<sup>th</sup> and 12<sup>th</sup>-grades, and in new books for only the 9<sup>th</sup>-grade. The chapter is one that has the least mathematical knowledge. It is the chapter with least mathematical knowledge in both versions. While there were eight pieces of mathematical knowledge in the chapter for old textbooks, the chapter contains seven pieces of mathematical knowledge in new textbooks.

The stars to quasars chapter is included only in the 11<sup>th</sup>-grade of the old books. The Optic chapter is only available in the 10<sup>th</sup>-grade of the new books. There are 29 pieces of mathematical knowledge in the stars to quasars chapter, while 52 pieces of mathematical knowledge are used in the Optic chapter. Besides this, the Energy chapter is only in the 9<sup>th</sup> grade books for both old and new versions. For this chapter, there are 39 pieces of mathematical knowledge in the new version, while there were only three pieces of mathematical knowledge in the old one.

### 3.2. Distribution of Mathematical Knowledge in Physics Textbooks According to Mathematical Subjects

In this section, the chapters in physics textbooks related to the mathematical knowledge as well as the findings of the distribution of categories according to class levels are included.

**Table 2.** Mathematical knowledge in physics books and their distribution according to grade levels

Categories	9. grade		10. grade		11. grade		12. grade		Total	
	O	N	O	N	O	N	O	N	O	N
Numbers and Operations	29	95	89	62	130	217	89	92	337	473
Algebra	8	48	24	15	41	68	17	59	90	190
Graphic	4	17	8	-	6	15	3	7	21	39
Transformation Geometry	-	1	3	37	4	17	5	-	12	55
Geometrical Concepts	10	5	16	23	26	43	7	7	59	75
Right Triangle and Trigonometry	6	5	24	4	30	41	16	21	76	71
Total	57	171	164	141	237	401	137	186	595	903

O: Physics textbooks used in 2011- 2012 academic year

N: Physics textbooks used in 2015- 2016 academic year

As it is seen in Table 2, mathematical knowledge in physics textbooks are examined through the categories of Algebra, Graph, Transformation Geometry, Geometrical Concepts, Right Triangle and Trigonometry. These categories do not include Graph Usage in the 10<sup>th</sup> grade version of the new textbooks, Graph Usage in 9<sup>th</sup>-grade version of the old textbooks, and Usage of Transformation Geometry in the 12<sup>th</sup>-grade edition of the new textbooks. The mathematical knowledge contained in the old version is about half of the knowledge covered in the new one. When grade levels are examined, it is found that the most advanced mathematics belongs to the 11<sup>th</sup>-grade textbooks of both old and new versions. The least mathematical knowledge is placed in the 9<sup>th</sup>-grade textbooks for both old and new versions. Outside of these grade levels, the mathematical knowledge covered in the versions seems to be approximate to each other.

Most of the mathematical knowledge used in textbooks of both versions belongs to the category of Numbers and

Operations. The Numbers and Operations category is also the most common category in books of all grades. The book for 11<sup>th</sup>-grade, in both cases, is included the most numbered pieces of mathematical knowledge in this category. The least mathematical knowledge in the same category is in the 9<sup>th</sup>-grade book for the old version, and in the 10<sup>th</sup>- grade textbook for the new version. Apart from other category, the number of the pieces of mathematical knowledge pertaining to the category of Numbers and Operations ranges from 89 to 95.

The Algebra category is among the most used mathematical category. This category is covered mostly in the 12<sup>th</sup>-grade book for the new version and least in the 9<sup>th</sup>-grade book for the old version. The Graph category contains the least mathematical knowledge in the new version. The category is mostly used in the 9<sup>th</sup>-grade book for the new version. Transformation Geometry is the least common mathematical category in old textbooks. The category, which is covered most in 10<sup>th</sup>-grade textbook in

the new version, is not covered at all in the old version of 9<sup>th</sup>-grade textbooks as well as in the new version of 12<sup>th</sup>-grade textbooks. Besides, the same category has been used in times range from one to five in most of the textbooks. The categories of Right Triangles and Trigonometry are in approximately the same amount for both versions in varying grades. The category, for the 9<sup>th</sup>-grade, is very limited in both versions. The mathematical knowledge regarding the same category is mostly covered in the textbooks for 11<sup>th</sup>-grades.

#### 4. Discussion and Conclusions

When the mathematical knowledge in the chapters is examined, it is seen that mathematics is mostly used in force and motion chapter. Moreover, when all physics chapters are evaluated, it is found that the most mathematical knowledge is in the same chapter of the 11<sup>th</sup>-grade textbooks. The fact that Force and Motion is the first chapter when it comes to teachers' usage of mathematics [9] supports this finding. The most mathematical knowledge in this chapter has caused certain students to have difficulties regarding mathematics-based science courses [28]. In this respect, further increase of the mathematical usage in the new-version textbooks can be considered as a measure taken for the students to encounter more mathematical knowledge and to close this gap to some extent. Some subjects in the mentioned chapter, such as Newton's Laws of Motion, focus more on mathematical issues compared to physics knowledge [17]. Many subjects are closely related to mathematics in the chapter content, such as Graph Interpretation, Ratio and Proportion, Chapter Conversion, Four Operations, and Speed Problems [45]. Besides, the chapter requires more geometry knowledge along with other mathematical subjects [46]. The fact the chapter contains excessive mathematical knowledge can be shown as another reason why this chapter occupies more compared to others within the overall volume of physics textbooks. In this direction, the chapter of Force and Motion emerges as an area in which mathematics applied to the real world [17]. The chapter contains concepts that are intertwined in terms of courses, physics, and mathematics. The reason why the chapter covers a bigger ratio of textbooks may be that it introduces the mathematical applications concretely. This can also be regarded as a consequence of the reflection of the interdisciplinary association of practical examples in different fields, and also of the recent popularity of STEM education, especially in textbooks.

When subjects covered in physics are evaluated, it is found out that, in both versions, the chapter of Introduction to Science of Physics requires the least mathematical knowledge. The Introduction to Science of Physics chapter includes subjects about the nature of physics rather than mathematical operations [46]. When the chapter content is

evaluated, it is seen that titles include Scalar and Vectoral Quantities, Errors in Measurements, and Observation [47]. This is, in particular, the result of the separation of the chapter of Nature of Physics from mathematics. Rather, the conceptual understanding methods used in the chapter focus on concepts and connections between the two. This led to the fact that the least mathematics usage in physics textbooks is placed in the chapter called Introduction to Science of Physics. However, it is stated that chapter conversion and vector operations are not included in the chapter, it is seen that mathematical operations related to these concepts are used [35]. In this respect, the inclusion of mathematics even in the subjects that contain the most conceptual knowledge in physics reveals an important connection between the two scientific disciplines.

When physics textbooks are evaluated in terms of mathematics usage, it is seen that the least amount of mathematical knowledge is in the 9<sup>th</sup>-grade of old textbooks. When we look at the structure of the old physics curriculum, it is seen that it adopts the physics understanding for everyone [47, 48]. In this respect, it is aimed to evaluate chapters in a simple and general frame with emphasis on daily life issues [49]. Considering that one cannot think of a totally separated physics from mathematics, it is inevitable to place mathematical subjects in old 9<sup>th</sup> grade physics textbooks even though it is not intended for. For this reason, the new physics curriculums of the 9<sup>th</sup> and 10<sup>th</sup>-grades have been transformed as basic physics, instead of physics for all [48], and mathematical knowledge of other grade levels is also put in such books as shown in Table 2. In the old textbooks, mathematical subjects had been increased in the advanced levels. However, teachers still considered those to be ineffective in the sense of mathematics usage and it has been stated that the narrative is too verbal [50]. For this reason, mathematical knowledge for all grade levels in the revised textbooks has been improved in terms of subjects and numerical understanding. Despite there has been an emphasis on conceptual teaching in physics classes, the increase of mathematics used in the new version textbooks can be shown as proof of how important mathematics is regarded for physics.

In both old and new textbooks, it is seen that, in all levels, Numbers and Operations is the subject containing the most mathematical knowledge. When the subject of numbers and operations is examined, it is seen that the category covered are the most commonly used mathematical knowledge in everyday life, which has been taught since the first stages of primary education. This subject is the basis of all mathematical operations because it contains subjects such as Rooted Numbers, Exponential Numbers, Rational Numbers, Chapter Conversion, Arithmetic and Geometric Mean and Four Operations. It should not be forgotten that the mathematical knowledge given in the first years of compulsory education covers potential solutions for problems that each person encounters in their

daily lives [51] and it is quite natural to use such knowledge in the later stages. The fact that physics textbooks have more of these chapters compared to other ones may be due to the fact that students are being asked to practice mathematical knowledge that they will use in everyday life. One of the reasons why the subject of numbers and operations is overly used in the textbooks is that the basis of many of the categories in mathematics requires the use of four operations [52]. Besides this, another reason can be expressed as it is imperative to help individuals to develop mathematical knowledge they most frequently encounter in their daily lives [53]. In this respect, it can be said that the chapter of Numbers and Operations, which is the most frequently used basic level mathematical knowledge in everyday life, is expected to be the most used mathematical knowledge in the textbooks as well.

The Algebra category takes second place as the mathematical knowledge in physics textbooks used in both two versions. Algebra, in the most general sense, examines the relations of general numbers, their properties, unknowns, formulas, patterns, placeholders, and associations [54]. In this respect, algebra contains many mathematical concepts, ranging from equations to proportionality, from problem-solving to derivatives that are related to physics. Hill decelerates that limited algebra knowledge is not sufficient for answering questions about electricity, and the chapter requires good algebra knowledge [26]. Besides, some researchers view Algebra as the most important mathematical category for physics [55]. In this direction, algebra is an indispensable mathematical category in all physics chapters.

While the graphics subject seemed to be more common in older books compared to the other mathematical subject, the same category is fewer in the new textbooks. On the other hand, in a study conducted with the seventh-grade students, Sezgin-Memnun [56] reported that most of the students were not successful in drawing graphics. It is also known that high school students have made too many mistakes in understanding, reading, and problem-solving of graphics [57]. Students mostly begin to draw graphs in their college years and have their first experiences with graphs at those times [58]. In this context, it is revealed that high school education cannot fully meet the deficiencies in graphics drawing. Graphics knowledge is often used in many physics chapters, from Force and Motion to Energy. In the textbooks examined, it is surprising that the mathematical knowledge about graphics knowledge is decreased. In order to correct this situation, more attention should be given to reading and understanding graphics in textbooks, and they should be supported with different subjects and concepts.

When we look at the mathematical knowledge in old and new physics textbooks, the most information is given about the subjects of numbers and operations, and algebra. The teaching of these chapters takes place either in the first stages of primary education or in the second stage during

the mathematics classes. For this reason, mathematics knowledge in physics textbooks of all levels is usually achieved through a basic level of expertise. The same knowledge, in addition, is knowledge that questions students' basic mathematical knowledge helps them remembering and developing mathematical knowledge.

Mathematics emerges as the most important area in terms of coverage in physics courses. Many mathematical subjects are included in the content of the physics is the best proof for that. Even though the emphasis is put on everyday life and conceptual based teaching, the most important consequence of the present study is that mathematics cannot be separated from physics. It is clear that it cannot be done without mathematical helping even if it emphasized to associate with daily life or conceptual understanding. Thus, highlighting the interdisciplinary relationship between the two disciplines for further studies will provide significant contributions to the development of both areas.

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