

A literature review on the definition of the concept of weight

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Abstract

The weight, one of the key concepts of physics education, still continues to be discussed among physics educators. Today, there are two main definitions as the ‘gravitational’ and ‘operational’, but there are differences even between them. It is important to know the different approaches found in textbooks in eliminating misconceptions and organizing the learning environment. Therefore, in this study, we examined the basic physics textbooks used as reliable sources in different universities in the world and aimed to reveal the differences of opinion in the literature in a single source. We examined the definitions in the textbooks for the concept of weight by using content analysis method in terms of vector and scalar characteristics. As a result of the analysis, we saw that the textbooks mostly (69.8%) define weight as a vector quantity. In addition, we determined that the definitions for being scalar started to be preferred after 2004. Moreover, we have determined that the gravitational and operational definitions have different interpretations, both as vectors and scalars, but the textbooks offer a single perspective for weight and do not include these different interpretations. We encountered the explanation of the differences of opinion in the literature only in one textbook.

Keywords: weight, gravity, force, vector, scalar

1. Introduction

The concept teaching and understanding the relationships between concepts are at the centre of physics education studies [1, 2]. The concept of ‘weight’, which is frequently encountered in daily life, is one of the important concepts of physics

course. The definition of the concept of weight, which finds its place in all physics subjects from mechanics to electricity and even nuclear physics, has occupied the scientific world since Ancient Greece.

Although it includes different interpretations, Plato and Aristotle defined weight as a ‘tendency’ that objects have. Archimedes, on the other hand, approached weight from a new point of view in his

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experiments on buoyancy, and it was defined as a force in the opposite direction with the buoyant force, which determines whether the object will sink or not for objects whose weight is thrown into the water [3]. Weight, which was a scalar concept until then, thus acquired vector properties. Two main definitions of weight are used today: 'gravitational' and 'operational' [4]. In the definition of 'gravitational', weight is defined as 'the gravitational force applied to an object' and relates it to the result of the act of weighing. In the 'operational' definition, the weight of an object is defined as 'the force that the object exerts on a supporting surface and prevents it from falling', that is, a distinction is made between weight and gravitational force [4, 5]. Although there are different opinions, both definitions similarly point out that weight is a 'force'.

However, discussions on the definition of weight still continue among physics educators. Hewitt [6] asked an interesting question on the best definition of weight. One of the striking answers belonged to Leong [7]: 'Instead of telling students that there is only one correct answer to a question, we may let them learn from a wider perspective'. Similarly, Morrison [8] pointed to the use of different definitions as the cause of confusion and argued that the physics teaching community should address the issue and agree on common definitions. Many researchers agreed with them, and they continued to offer different suggestions. For example, Brown [9] and Louro [10] suggested never using the word 'weight'. Brown [9] suggested 'force due to gravity' instead. According to Louro [10], there was no need to give it a special name; it could be attributed to gravitational acceleration when discussing the acceleration of a free-falling object. But Bartlett [11] found this misleading as expressing 'weight' was a combination of the 'gravitational force' and the force needed to provide the centripetal acceleration of a test mass at rest on the surface of the rotating Earth.

As another suggestion, Bishop [12] stated that he thought using the operational definition would solve the problem. Iona [13] suggested avoiding the term weight in its meaning as a force. Taibu [14] stated that there were language problems associated with each gravitational and operational definition of weight. He recommended the

use of other concept representations such as direct phrases (e.g. gravitational forces, scale forces, etc.), figures, simulations, and explicitly telling students to be careful with language. Similarly, Sokolowski [15] also suggested the demonstration method to teach the difference between the force of gravity and weight.

It has been found that weight causes confusion in studies conducted among students of different education levels, as well as among educators [4, 16–23]. Especially since the end of the 1980s, it is seen that studies on misconceptions about gravity, mass and weight have increased in the physics education literature [24]. In these studies, it was determined that students did not understand the relationship between weight and gravity [20, 25] and could not distinguish between mass and weight [26]. In addition, it has been observed that the misconception that the cause of falling objects is their weight [27, 28] and that heavy objects will fall faster [21, 24, 29, 30] are common.

In the studies conducted with the teachers, it was seen that they could distinguish between weight and gravity, but based on the definition of weight as the force of gravity, they reached the conclusion that heavy and light objects have the same weight [31]. In one study, it was determined that the teachers in the study group were not sure whether weight is a force, and almost half of the teachers said that weight is not a force, while the other half defined weight as gravity [32]. No study was found in which teachers stated that there are different definitions for the concept of weight. A striking point in the studies investigating misconceptions about weight is that one of the weight concepts in the literature is accepted as correct, while the other definition is pointed out as a misconception [33–35]. It is thought that the reason for this situation is the lack of awareness of the differences of opinion in the literature or the different approaches adopted in the textbooks. Identifying a point of view in a textbook as a misconception may cause inconsistency in the educational environment. The reliability of the data obtained from these studies may be affected by this situation. The findings of these studies may lead to incorrect directions for researchers who want to conduct similar studies. A similar potential problem may also apply to teachers who will structure their lessons

on misconceptions in the literature. Due to the confusion that will arise, new applications to be developed for an effective teaching, experiments, studies containing materials or new resources to be written may not reach their purpose.

For all these possible results, in this study, we tried to determine how these books approach the concept of weight by examining the basic physics books used at university level in many countries from past to present. Thus, we aimed to provide researchers and educators the opportunity to see the definitions in the textbooks for the concept of weight together, to raise awareness about the different tendencies towards the concept of weight and to help them have knowledge.

2. Method

This section describes the sources we reviewed and the method we used to analyse them.

2.1. Sample

Initially, we chose printed basic physics textbooks in the library of Gazi University in Turkey and in the personal libraries of the faculty members of the physics education department of this university. Then, we added physics books that can be accessed with full texts available through internet search engines. For the 66 books obtained, we determined the following criteria by taking the opinions of three faculty members who took an active role in the teaching of basic physics courses:

- intended for physics or engineering students
- be in English or have an English version
- based on algebra and calculus
- given a definition for the concept of 'weight'.

According to the evaluation, we have examined 53 basic physics books that meet these criteria. This method for textbook selection has also been used in similar studies in the literature [36, 37]. Considering the possibility of differences in updated editions, we included different available editions of the same books in the analysis. The textbooks analysed are listed in table 1.

2.2. Procedure

We analysed the textbooks independently by two researchers. We used content analysis in the analysis of the data. The content analysis studies have the feature of making the findings in the literature more accessible, higher-level abstraction and generalization [38]. In this respect, it presents the subject from a holistic perspective. It provides a rich source of reference for researchers working in the relevant field by providing a qualitative synthesis of common and similar aspects in researches that approach the subject from different perspectives [39, 40]. For this reason, the content analysis is frequently used in studies where textbooks are analysed [37, 41].

Before starting the analysis, we examined the parts of the books describing force, weight, mass, Newton's Laws, free fall, circular motion and buoyant force. In these sections, we determined the definitions for weight. For analysis, we tried to find answers to the following questions:

- What is the definition used for weight?
- Is the concept of weight presented as scalar or vector?

We answered the above questions by creating a checklist, as it guides us to properly determine the features sought for analysis in content analysis studies [41].

To answer the second question, we examined the definitions in the books. We accepted the definitions with 'magnitude' as scalar. In the case of 'vector definition', we concluded that it is related to the appearance of the term 'force' in the definition due to the nature of the force. If we go into a little more detail, it is known that one of the most understandable ways to represent vector quantities is to use unit vectors such as $\hat{i}$, $\hat{j}$, $\hat{k}$. For example, in a quantity $\vec{A}$ represented as $\vec{A} = a\hat{i}$, it is clear that $\vec{A}$ is a vector quantity. Here $\hat{i}$ denotes the direction of vector $\vec{A}$. a is the magnitude of vector $\vec{A}$ and is a positive number with no direction, so it is a scalar quantity. We can rewrite this example as $\vec{F}_g = w(-\hat{j})$ for weight. There is no consensus on which of the $\vec{F}_g$ and w are defined as weights here. If $\vec{F}_g$ is defined as the weight, then the weight represents a force as a vector quantity

Table 1. List of physics textbooks analysed.

Book code	Textbook
B1	Alrasheed, S (2019). <i>Principles of Mechanics</i> . Springer.
B2	Asimov, I (1969). <i>Understanding Physics (Vol. I: Motion, Sound & Heat)</i> . Dorset Press.
B3	Bennett, C E (1937). <i>An Outline of First Year College Physics</i> . Barnes & Noble Inc.
B4	Carhart, H S (1910). <i>Physics for College Students</i> . Allyn and Bacon.
B5	Crew, H (1908). <i>General Physics: An Elementary Text-Book for Colleges</i> . The MacMillan Company.
B6	Crowell, B (2017). <i>Mechanics</i> . Light and Matter.
B7	Cutnell, J D <i>et al</i> (2012). <i>Physics</i> (9th ed.). John Wiley and Sons.
B8	Cutnell, J D, & Johnson, K W (2004). <i>Physics</i> (6th ed.). John Wiley & Sons.
B9	Fazely, A R (2015). <i>Foundation of Physics for Scientists and engineers (Vol. I: Mechanics, Heat and Sound)</i> . Bookboon.
B10	Fishbane, P M <i>et al</i> (2005). <i>Physics for Scientists and Engineers with Modern Physics</i> (3rd International ed.). Pearson.
B11	Fischer-Cripps, A C (2014). <i>The Physics Companion</i> (2nd ed.). CRC Press.
B12	Giambattista, A (2020). <i>Physics</i> (5th ed.). McGraw-Hill Education.
B13	Giambattista, A <i>et al</i> (2010). <i>College Physics with an Integrated Approach to Forces and Kinematics</i> (3rd ed.). McGraw-Hill.
B14	Giancoli, D C (2005). <i>Physics: Principles with Applications</i> (6th ed.). Pearson/Prentice Hall.
B15	Giancoli, D C (2016). <i>Physics: Principles with Applications</i> (7th ed.). Pearson/Prentice Hall.
B16	Griffith, W T (2022). <i>The Physics of Everyday Phenomena, A conceptual Introduction to Physics</i> (10th ed.). McGraw-Hill Education.
B17	Haler, P J (1921). <i>An Introduction to Physics</i> . Library Press.
B18	Halliday, D, & Resnick, R (2014). <i>Fundamentals of Physics</i> (10th ed.) (J Walker, Ed.). Wiley.
B19	Halliday, D, & Resnick, R (2018). <i>Fundamentals of Physics</i> (Extended 10th ed.) (J Walker, Ed.). Wiley.
B20	Hawkes R <i>et al</i> (2019). <i>Phycis for Scientists and Engineers, An Interactive Approach</i> (2nd ed.). Nelson.
B21	Hewitt, P (2015). <i>Conceptual Physics</i> (12th ed.). Pearson.
B22	Katz, D M (2017). <i>Physics for Scientists and Engineers, Foundations and Connections with Modern Physics</i> . Cengage Learning.
B23	Knight, R D (2008). <i>Physics for Scientists and Engineers</i> (2nd ed.). Pearson.
B24	Knight, R D (2016). <i>Physics for Scientists and Engineers: A Strategic Approach</i> (4th ed.). Pearson.
B25	Kuhn, K F (1996). <i>Basic Physics, A Self Teaching Guide</i> (2nd ed.). John Wiley & Sons, Inc.
B26	Ling, S, Sanny, J, & Moebs, W (2018). <i>University Physics</i> (Vol. 1). OpenStax.
B27	Mann, C R, & Twiss, G R (1910). <i>Physics</i> . Chicago, Scott, Foresman and Co.
B28	Matolyak, J, & Haija, A (2013). <i>Essential Physics</i> . CRC Press.
B29	Matthews, C P, & Shearer, J S (1899). <i>Problems and Questions in Physics</i> . The Macmillan Company.
B30	Orear, J (1961). <i>Fundamental Physics</i> . John Wiley & Sons, Inc.
B31	Radi, H A, & Rasmussen, J O (2013). <i>Principles of Physics for Scientists and Engineers</i> . Springer.
B32	Resnick, R <i>et al</i> (2002). <i>Physics</i> (Vol. 1) (5th ed.). John Wiley & Sons, Inc.
B33	Rex, A (2014). <i>Commonly Asked Questions in Physics</i> (1st ed.). CRC Press.
B34	Schnick, J W (2008). <i>Calculus-Based Physics I</i> . CreateSpace Independent Publishing Platform.
B35	Serway, R, & Beichner, R J (2007). <i>Physics for Scientists and Engineers with Modern Physics</i> (Vol. 1) (5th ed.). Palme.
B36	Serway, R A, & Faughn J S (2006). <i>Physics</i> . Holt, Rinehart and Winston.
B37	Serway, R, & Jewett, J W (2004). <i>Physics for Scientists and Engineers (with PhysicsNOW and InfoTrac)</i> (6th ed.). Brooks/Cole-Thomson Learning.

(Continued.)

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Table 1. (Continued.)

Book code	Textbook
B38	Serway, R, & Jewett, J W (2006). <i>Principles of Physics: A Calculus-Based Text</i> (4th ed.). Brooks/Cole-Thomson Learning.
B39	Serway, R, & Jewett, J W (2014). <i>Physics for Scientists & Engineers & Modern Physics</i> (9th ed.). Brooks/Cole-Thomson Learning.
B40	Serway, R A, & Vuille, C (2012). <i>College Physics</i> (9th ed.). Brooks/Cole-Thomson Learning.
B41	Tipler, P A, & Mosca, G (2003). <i>Physics for Scientists and Engineers with Modern Physics</i> (4th ed.). W H Freeman and Company.
B42	Tipler, P A, & Mosca, G (2008). <i>Physics for Scientists and Engineers with Modern Physics</i> (6th ed.). W H Freeman and Company.
B43	Tsokos, K A (2014). <i>Physics for the IB Diploma</i> (6th ed.). Cambridge University Press.
B44	Urone, P P, & Hinrichs, R (2013). <i>College Physics</i> . OpenStax College.
B45	Walker, J S (2007). <i>Physics</i> (3rd ed.). Pearson.
B46	Walker, J S (2017). <i>Physics</i> (5th ed.). Pearson.
B47	Wolfson, R (2021). <i>Essential University Physics</i> (4th ed., Global ed.). Pearson.
B48	Woodside, R (2011). <i>International As and a Level Physics Revision Guide</i> . Hodder Education.
B49	Yorke J P (1916). <i>Elementary Physics for Engineers</i> . Cambridge University Press.
B50	Young, H D, & Freedman, R A (2012). <i>Sears and Zemansky's University Physics with Modern Physics</i> (13th ed.). Pearson.
B51	Young, H D, & Freedman, R A (2016). <i>Sears and Zemansky's University Physics with Modern Physics</i> (14th ed.). Pearson.
B52	Young, H D, & Freedman, R A (2019). <i>University Physics with Modern Physics</i> (15th, Global ed.). Pearson.
B53	Zitzewitz, P W <i>et al</i> (2005). <i>Physics, Principles and Problems</i> . The McGraw-Hill Companies.

and w is the magnitude of the weight. However, in the above notation, if w , the magnitude of the vector quantity $\vec{F}_g$, is defined as weight, then weight is considered a scalar quantity. In this case, the quantity $\vec{F}_g$ becomes a quantity represented by the product of the positive number, weight (w) and the unit vector ($-\hat{j}$), often called the gravitational force. This criterion was taken as a basis when deciding whether the definition of weight is a vector or a scalar in the reviewed sources. We use this criterion because there are other examples where the magnitude of the force is defined as a scalar. For example, when a rope attached to an object is pulling on the object, the rope exerts a force on the object in a direction away from the object, parallel to the rope. The magnitude of that force is called the tension in the rope. Because it is the magnitude of a vector quantity, tension is a scalar quantity.

In order to ensure validity and dependability, we placed the definitions in the books in a table by quoting directly. We first coded these definitions as vectors or scalars. Then, we

inductively grouped together definitions with similar content and categorized them. In order to ensure dependability, we resorted to peer debriefing and received opinions from two physics education experts regarding the suitability of the categories. As a result of our discussions about the differences of opinion, we achieved 100% agreement.

In order to ensure transferability in the study, we used the detailed description method by explaining the criteria for determining the books included in the research, data collection and analysis processes for confirmability. In order to increase credibility, we used the definitions in the books by quoting directly and without adding comments. We have provided the list of textbooks reviewed for confirmability and archived the analyses for availability upon request. We digitized the results of the analysis as frequency values for each category. Digitizing the data is important in terms of the reliability of the research as well as providing the opportunity to compare the findings if the research is repeated [42].

Table 2. Scalar definitions of weight in the textbooks analysed.

Category f (%)	Definition	Book code	Book year
The magnitude of the gravitational force $f = 14$ (26.4%)	We call the size of the gravitational force (also called the strength, or magnitude, of the force) that a planet or moon exerts on a nearby object the object's weight.	B12 ^a	2020
	Your weight is the magnitude of Earth's gravitational force exerted on you.	B13	2010
	The magnitude of the force of gravity on an object, mg , is commonly called the object's weight.	B15	2016
	The weight W a body is equal to the magnitude F_g of the gravitational force on the body.	B18	2018
	We define the weight W of any object to be the magnitude of the gravitational force acting on the object.	B22 ^a	2017
	For an object at rest on the surface of a planet, its weight is simply the magnitude F_G of the gravitational force.	B24 ^a	2016
	The magnitude of the gravitational force is called the weight F_g of the object.	B27	1910
	This force (gravity) is directed toward the centre of the Earth, and its magnitude is called the weight of the object.	B35	2007
	This force (gravity) is directed toward the centre of the Earth, and its magnitude is called the weight of the object.	B39	2014
	The gravitational force exerted on the ball by Earth, $\vec{F}_g$, is a vector quantity, directed toward the centre of Earth. The magnitude of this force, F_g , is a scalar quantity called weight.	B36 ^a	2006
	The weight of an object is equal to the magnitude of the gravitational force exerted on the object and varies with location.	B37	2004
	The weight of the object is the magnitude of the gravitational force on it.	B38	2006
	The magnitude of the gravitational force acting on an object of mass m is called the weight w of the object.	B40	2012
	The <i>weight</i> of the object is the magnitude of the gravitational force on it.	B42	2008
A measure $f = 3$ (5.7%)	Weight, ..., is a measure of the gravitational pull on an object.	B12 ^a	2020
	Weight is a measure of the gravitational force acting on an object.	B22 ^a	2017
	Weight: a measure of the gravitational force exerted on an object.	B36 ^a	2006
A measurement $f = 2$ (3.8%)	Weight is a measurement, the result of 'weighing' an object.	B23	2008
	Weight is a measurement, the result of 'weighing' an object.	B24 ^a	2016
The magnitude of balancing force $f = 1$ (1.9%)	The weight W of a body is the magnitude of the upward force needed to balance the gravitational force on the body.	B19	2018

^a More than one definition is given in the textbook.

3. Result and discussion

In this part of the research, there are findings regarding the weight definitions in the specified textbooks. We examined the definitions in the textbooks under two headings as scalar definitions and vector definitions. We classified the research findings and tabulated them as frequency and percentage results. The scalar definitions of weight in the

textbooks we examined in the study are classified and given in table 2.

As can be seen in table 2, there are 16 different books (B12, B13, B15, B18, B22, B24, B27, B35, B39, B36, B37, B38, B40, B42, B23, B19) in which weight is defined as scalar quantity among the 53 books reviewed. That is, in about 30.2% of the books reviewed, weight is defined as a scalar

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Table 3. Vector definitions of weight in the textbooks analysed.

Category f (%)	Definition	Book code	Book year
The force of gravity $f = 21$ (37.7%)	Weight is the force of gravity.	B3	1937
	The mass of any particle multiplied by the acceleration of gravity measures the force with which this particle is drawn towards the earth,—a force which is ordinarily called the weight of the body.	B5	1908
	In physics, an object's weight, F_w , is defined as the earth's gravitational force on it.	B6	2017
	The weight of an object on or above the earth is the gravitational force that the earth exerts on the object.	B7	2012
	The weight of an object on or above the earth is the gravitational force that the earth exerts on the object.	B8	2004
	...the force of gravity on an object is commonly called the object's weight.	B10	2005
	Weight... is a force, the pull of gravity acting on an object.'	B14	2007
	The gravitational force acting on an object is the weight of the object.	B16	2022
	The weight of a body is the force which gravity exerts upon it, $W = mg$.	B17	1921
	Weight: Usually the force upon an object due to gravity.	B21	2015
	The downward force of the Earth's gravity acting on the body is called the weight of the body.	B32	2002
	If air resistance is negligible, the net force on a falling object is the gravitational force, commonly called its weight $\vec{W}$, or its force due to gravity acting on an object of mass m .	B26 ^a	2018
	Weight (also called the force of gravity) is a pervasive force that acts at all times and must be counteracted to keep an object from falling.	B26 ^a	2018
	Weight is the force of gravity.	B33	2014
	The gravitational force exerted on an object by the earth's gravitational field (or that of another planet when the object is near the surface of that other planet) is sometimes called the weight of the object.	B34	2008
	The weight $\vec{W}$ of an object is the force of gravitational attraction exerted by earth on the object.	B41	2003
	This force (weight) is the result of the gravitational attraction between the mass m of a body and the mass of the planet on which the body is placed.	B43	2014
	Weight ..., by definition, the direction of gravity, ...	B44 ^a	2013
	If air resistance is negligible, the net force on a falling object is the gravitational force, commonly called its weight.	B44 ^a	2013
	The weight, W , of an object on the Earth's surface is the gravitational force exerted on it by the Earth.	B45	2007
	A mass in a gravitational field experiences a force. We have already seen that the size of the force depends on the strength of the gravitational field and the mass of object: $F = mg$ where F = force (or weight)...	B48	2011
	The weight, W , of an object on the Earth's surface is the gravitational force exerted on it by the Earth.	B46	2017
	Weight is the force that gravity exerts on a body.	B47	2021

(Continued.)

Table 3. (Continued.)

Category f (%)	Definition	Book code	Book year
The force exerted by the Earth $f = 13$ (24.5%)	W is known as the weight of an object and is defined as the gravitational force exerted on it by earth (or any other astronomical body, where g is different than that of earth).	B1	2019
	The weight of a body is the force with which it is attracted to the earth.	B2	1969
	The force with which the earth attracts a body is known in science as weight.	B4	1910
	The gravitational force exerted by Earth on a mass near the surface of Earth is sometimes referred to as the weight of the object.	B20	2019
	Weight is a force that is due to the earth's pull of gravity.	B25	1996
	Weight is the pull of Earth on an object.	B26 ^a	2018
	The notion 'weight' of the object is the force by which the object is attracted to the Earth.	B28	2013
	The weight of a body, therefore, is the force with which it is drawn towards the earth, or with which the earth is drawn towards it.	B29	1899
	The weight $\vec{W}$ of a body is the force exerted by the Earth on the body.	B31	2013
	Weight is simply the force of attraction between the matter and the earth.	B49	1916
	Weight, on the other hand, is a <i>force</i> exerted on a body by the pull of the earth.	B50	2012
	The gravitational force that the earth exerts on your body is called your weight.	B51	2016
	The gravitational force that the earth exerts on your body is called your weight.	B52	2019
Unbalanced force on the body $f = 1$ (1.9%)	... That is, the unbalanced force acting on the body is its weight W . $W = mg$	B11	2014
The force of the object against the floor $f = 1$ (1.9%)	The weight; of an object is defined as the force of the object against the floor.	B30	1961
A field force $f = 1$ (1.9%)	A field force due to gravitational attraction between two objects, generally Earth and an object.	B53	2005
A force $f = 1$ (1.9%)	Weight, ..., is a force (a vector) and be defined by Newton's second law when a is replaced with g .	B9	2015

^a More than one definition is given in the textbook.

quantity. In most of these books ($f = 14$; 26.4%), the weight is defined as 'the magnitude of the gravitational force'. It is defined as 'a measure' in three books (5.7%) and as 'a measurement' in two books (3.8%). This has been explained in different ways as the measure of the force of gravity and the

object being weighed. In one book (1.9%), it was included as 'the magnitude of balancing force'. Looking at the publication years of these books, it was seen that one (1.9%) was published in 1910, six (11.3%) between 2004–2009, and 9 (17%) in 2010 and after.

The vector definitions of weight in the textbooks examined in the study are given in table 3 as classified.

As seen in table 3, there are 37 different books in which weight is defined as a vector quantity among the 53 books reviewed. That is, in about 69.8% of the books reviewed, weight is defined as a vector quantity. In the definition of weight in these books, 'force' is emphasized for weight. In most of these books ($f = 21$; 39.6%), weight is defined as 'the force of gravity'. In 13 books (24.5%), various expressions are used to mean that it is the gravitational force exerted by the earth. It is defined as 'unbalanced force on the body' and 'force of the object against the floor', 'a field force' and 'a force' in each book (1.9%).

Looking at the publication years of the books in table 3, nine books (17.0%) were published before 2000, seven (13.2%) were published between from 2000 to 2009, and 21 (39.6%) were published in 2010 and later. From this, it can be seen that the vector definition in the books fluctuates more over the years.

4. Conclusion

In our study, it was investigated whether the definitions of weights in basic physics textbooks differed. The study findings showed that textbooks mostly (79.2%) define weight as a vector quantity. These findings on textbook definitions related to weight are similar to previous studies [4, 37]. When the publication years of the books are taken into account, we have seen that this preference does not show a trend according to the years. However, we determined that almost all of the books that included scalar were published after 2004.

As a result of the study, we saw that the gravitational and operational definitions accepted in the literature were interpreted in different ways within themselves. In particular, it has been determined that some of the books that use the gravitational definition explain weight with a vector expression as 'gravity force itself', while others explain the same definition with a scalar expression as 'the magnitude of the gravitational force'. From this point of view, it is understood that there is no consensus even among those who

adopt the same definitions, and that there are differences in interpretation. We think that these differences will be challenging for students who try to understand the concept by using different sources.

Moreover, we determined that there is also the expression 'magnitude of the weight' in the books (11.3%) coded as B7, B12, B46, B50, B51 and B53, which define the weight as vector. This situation is likely to create confusion in the mind of a student who has learned that weight is the 'magnitude of the gravitational force'.

An important point that draws our attention in the research findings is that almost all of the textbooks present only the approach adopted in the book, while other alternative approaches and the situation in the literature are ignored. Similar results were obtained in other studies [4, 37].

We have seen the change in the definition of weight in different editions of the book, in the B14 coded book belonging to the same author and publisher. A vector definition ('Weight... is a force, the pull of gravity acting on an object.') is used in the 6th edition of this book dated 2007. In the B15 coded 7th edition of 2016, we determined that the previous definition was revised and replaced with a scalar definition ('The magnitude of the force of gravity on an object, mg , is commonly called the object's weight'). We could not find any explanation for the reason for this change.

In addition to the definition of weight, we encountered a different weight concept in the form of 'apparent weight' in 29 (54.7%) of the books reviewed. In 17 (32.1%) books (B7, B12, B13, B15, B18, B19, B20, B22, B26, B28, B36, B41, B44, B52, B54), a definition was made by associating the concept of 'apparent weight' with the buoyant force and the value displayed by the scale in the elevator. Some of these are: 'In general, an apparent weight is related to the actual weight of a body and the buoyant force on the body by ($\text{Weight}_{\text{app}} = \text{weight} - F_b$)' (B18, B19) 'The weight would take on a different value if measured high on a mountain, or in an elevator that was accelerating. Some prefer to call the reading in these circumstances the apparent weight.' (B20) 'The weight of an object immersed in a fluid is the object's apparent weight.' (B36) 'The force exerted by the scale is called the apparent weight.'

An object's apparent weight is the force an object experiences as a result of all the forces acting on it, giving the object an acceleration.' (B54). Also, 12 (22.6%) books (B6, B14, B16, B31, B32, B35, B37, B38, B39, B40, B47, B51) also include this concept and give examples, although they do not provide a definition for 'apparent weight'.

We think that finding differences between the textbooks used by students for a concept that students have difficulty in understanding may make the situation even more difficult. Since students do not know the reason for these different approaches, they may find these statements contradictory and may be confused about which one to learn. In addition to the differences between the books, it can be quite confusing for students to find different approaches even in the same source without explaining the reason for the difference. Among the books, we examined, only the B20 coded book mentions the existence of a difference of opinion in the literature. In this book, after the definition of 'the gravitational force exerted by Earth on a mass near the surface of Earth', the following explanation is given: 'There is no agreement within the physics community on how weight should be defined'.

The literature shows that the confusion regarding the definition of the concept can have serious consequences [8]. We think that having similar explanations in other books and talking about the differences of opinion in the literature can prevent students from getting confused. It has been stated that it is not possible to develop a rich understanding with a single definition in the studies in which the definition of weight is discussed in the literature [43]. Instead of presenting a single correct answer to the students, it has been suggested to provide a wider perspective [7, 43] and to present a compound definition for concepts that include different aspects of them [44]. In this respect, we attach importance to presenting different definitions adopted in the new editions of textbooks, and we believe that this will be more informative for students.

Even if it is not in the textbooks, teachers' informing the students of these different approaches in the literature while teaching the concept of weight and discussing the semantic

differences can enable the concept to be built on a more solid basis. It has been recommended in many studies that teachers use the concepts in the teaching environment, knowing the change over time [34, 43, 45]. However, Galili and Lehari found in their study [4] with teachers, similar to the findings we obtained from textbooks, that very few of the teachers (17%) defined weight as both scalar and vector; however, they did not provide an explanation for the inconsistency of the two. We believe that teachers, researchers and textbook authors, should take the holistic approach that we tried to put forward in this study regarding the concept of weight into account and it can prevent problems in the teaching environment.

Data availability statement

No new data were created or analysed in this study.

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References

- [1] Hobson A 2003 *Physics: Concepts and Connections* 3rd ed. (Upper Saddle River, NJ: Prentice Hall/Pearson Education)
- [2] Duit R, Gropengießer H and Kattmann U 2005 Towards science education research that is relevant for improving practice: the model of educational reconstruction *Developing Standards in Research on Science Education* ed H E Fischer (London: Taylor & Francis) pp 1–9
- [3] Archimedes S 1978 *On Floating Bodies* (Chicago, IL: Encyclopaedia Britannica) Book II, 540, 543
- [4] Galili I and Lehari Y 2003 The importance of weightlessness and tides in teaching gravitation *Am. J. Phys.* **71** 1127–35
- [5] Balukovic J and Slisko J 2018 Teaching and learning the concept of weightlessness: an

A literature review on the definition of the concept of weight

- additional look at physics textbooks *Eur. J. Phys. Educ.* **9** 1–14
- [6] Hewitt P 2013 Weight *Phys. Teach.* **51** 330
- [7] Leong W C 2013 Is there a best definition of weight? *Phys. Teach.* **51** 516–7
- [8] Morrison R C 1999 Weight and gravity—the need for consistent definitions *Phys. Teach.* **37** 51–52
- [9] Brown R 1999 Weight—don’t use the word at all *Phys. Teach.* **37** 241
- [10] Louro A 2011 Banish “weight”? *Phys. Teach.* **49** 196
- [11] Bartlett A A 2010 “Apparent weight”: a concept that is confusing and unnecessary *Phys. Teach.* **48** 522–4
- [12] Bishop R 1999 Weight—an accurate, up-to-date, Layman’s definition *Phys. Teach.* **37** 238–9
- [13] Iona M 1975 The meaning of weight *Phys. Teach.* **13** 263–74
- [14] Taibu R 2017 Terms vs. concepts—the case of weight *Phys. Teach.* **55** 34–35
- [15] Sokolowski A 1999 Weight—a pictorial view *Phys. Teach.* **37** 240
- [16] Dostal J A 2005 Student concepts of gravity *Doctoral Dissertation* Iowa State University
- [17] Feeley R E 2007 Identifying student concepts of gravity *Doctoral Dissertation* University of Maine
- [18] Galili I and Bar V 1997 Children’s operational knowledge about weight *Int. J. Sci. Educ.* **19** 317–40
- [19] Galili I and Kaplan D 1996 Students’ operation with the concept of weight *Sci. Educ.* **80** 457–87
- [20] Gönen S 2008 A study on student teachers’ misconceptions and scientifically acceptable conceptions about mass and gravity *J. Sci. Educ. Technol.* **17** 70–81
- [21] Kavanagh C and Sneider C 2007 Learning about gravity I. Free fall: a guide for teachers and curriculum developers *Astron. Educ. Rev.* **5** 21–52
- [22] Ruggiero S, Cartelli A, Dupre F and Vicentini-Missoni M 1985 Weight, gravity and air pressure: mental representations by Italian middle school pupils *Eur. J. Sci. Educ.* **7** 181–94
- [23] Watts D M 1982 Gravity—don’t take it for granted! *Phys. Educ.* **17** 116–21
- [24] Stein M, Larrabee T G and Barman C R 2008 A study of common beliefs and misconceptions in physical science *J. Elem. Sci. Educ.* **20** 1–12
- [25] Trumper R and Gorsky P 1997 A survey of biology students’ conceptions of force in pre-service training for high school teachers *Res. Sci. Technol. Educ.* **15** 133–47
- [26] Galili I 2001 Weight versus gravitational force: historical and educational perspectives *Int. J. Sci. Educ.* **23** 1073–93
- [27] Bar V, Zinn B, Goldmuntz R and Sneider C 1994 Children’s concepts about weight and free fall *Sci. Educ.* **16** 149–70
- [28] Selman R, Krupa M, Stone C and Jaquette D 1982 Concrete operational thought and the emergence of the concept of unseen force in children’s theories of electromagnetism and gravity *Sci. Educ.* **66** 181
- [29] Celemin M and Covian E 1999 Misconceptions in mechanics in first year engineering students *Proc. ICEE’99 Conf. (August 1999)* pp 10–14
- [30] Champagne A, Klopfer L and Anderson J 1980 Factors influencing the learning of classical mechanics *Am. J. Phys.* **48** 1074–9
- [31] Smith R and Peacock G 1992 Tackling contradictions in teachers’ understanding of gravity and air resistance *Eval. Res. Educ.* **6** 2–3, 113
- [32] Kruger C, Palacio D and Summers M 1992 Survey of English primary teachers’ conceptions of force, energy and materials *Sci. Educ.* **76** 339–51
- [33] Koray Ö and Tatar N 2003 Misconceptions of primary school students about mass and weight and the distribution of these misconceptions by 6th, 7th and 8th grades *Pamukkale Üniv. J. Sci. Math. Educ.* **1** 13
- [34] Métioui A and Trudel L 2021 Children and preservice teachers’ misconceptions and scientifically acceptable conceptions about movement, force, and gravity *Mod. Perspect. Lang. Lit. Educ.* **5** 26–42
- [35] Mongan S W, Mondolang A H and Poluakan C 2020 Misconception of weights, normal forces and Newton third law *J. Phys.: Conf. Ser.* **1572** 012046
- [36] Niaz M, Klassen S, McMillan B and Metz D 2010 Reconstruction of the history of the photoelectric effect and its implications for general physics textbooks *Sci. Educ.* **94** 903–31
- [37] Taibu R, Rudge D and Schuster D 2015 Textbook presentations of weight: conceptual difficulties and language ambiguities *Phys. Rev. Spec. Top. Phys. Educ. Res.* **11** 010117
- [38] Zimmer L 2006 Qualitative meta-synthesis: a question of dialoguing with texts *J. Adv. Nurs.* **53** 311–8
- [39] Çalık M and Sözbilir M 2014 Parameters of content analysis *Educ. Sci.* **39** 33–38
- [40] Bağ H and Çalık M 2017 A thematic review of argumentation studies at the K-8 level *Educ. Sci.* **42** 281–303

- [41] Ibáñez M and Ramos M C 2004 Physics textbooks presentation of the energy-conservation principle in hydrodynamics *J. Sci. Educ. Technol.* **13** 267–76
- [42] Yıldırım A and Simsek H 2005 *Sosyal Bilimlerde Nitel Araştırma Yöntemleri (Qualitative Research Methods in the Social Sciences)* (Turkey: Seckin Publishing)
- [43] Bar V, Brosh Y and Sneider C 2016 Weight, mass, and gravity: threshold concepts in learning science *Sci. Educ.* **25** 22–34
- [44] Galili I and Lehavi Y 2006 Definitions of physical concepts: a study of physics teachers' knowledge and views *Int. J. Sci. Educ.* **28** 521–41
- [45] Métioui A and Trudel L 2018 Life-world knowledge, and scientific knowledge: an epistemological rupture *Adv. Soc. Sci. Res. J.* **5** 398–405



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