A Discussion on an Expression Written about Dimensional Analysis in a Physics Textbook

Ali Yıldız

Atatürk University, Kazım Karabekir Faculty of Education
Department of Primary Education, Erzurum, Turkey
ayildiz@atauni.edu.tr

(Received: 28.05.2015, Accepted: 27.07.2015)

Abstract
The purpose of this study is to discuss a wrong statement written about dimensional analysis in a physics text book prepared for the students who are studying in science, engineering and teaching undergraduate programs at universities and who have to take compulsory physics courses, to analyse the use of the text book including the wrong expression and its effects, and to define it again. Document analysis is used as the main method of data collection instrument in qualitative studies. The data of this qualitative study were gathered by examining the documents such as book or scientific paper published on the subject with a descriptive analysis method. The attention drawing statement in the physics textbook commonly used around the word is, "All quantities can be converted into length, time and mass units in the end. No matter how complex any physical quantity is, it is stated as algebraic combination of these three basic quantities." The most important findings of this study are as follows: the wrong description about dimensional analysis will not only be a book error, it will lead to misconceptions, and it will hinder learning dimensional analysis correctly and students' studying physics course.
Keywords: Physics reference book, mistakes in the book, fundamental dimensions, dimensional analysis, document analysis

Introduction

It is widely known that despite the developing technology with a broad implementation area, textbooks are one of the printed materials that are used directly and without any alternatives, and they play an active and important role in education at all levels. The biggest advantage of printed materials is that that they enable individuals to revise information several times and to study independently. Textbooks examine and explain the knowledge included in the curriculum in a planned and organized way, and they are also the basic documents, which facilitate and educate students in line with the goals and objectives of the course as a source of knowledge (Ünsal and Güneş, 2004). The research studies revealed that science textbooks are filled with conceptual errors, irrelevant pictures, confusing demonstrations, experiments which are impossible to do, and full of diagrams and depictions which present impossible cases, and the necessary connection between the texts and visuals are not established in many textbooks (Bean, Searles, Singer & Cowen, 1990; Reid 1990; Lord, 2001; Ünsal and Güneş, 2004; Özay and Hasenekeoğlu, 2007).

Yildiz (2013) conducted a study that explored the errors, which pre-service teachers noticed while taking compulsory mechanics and electricity courses in the textbooks and their opinions about using these textbooks. The pre-service teachers (62.6%) had negative views about the existing errors in physics textbooks and explained them in writing. They stated, "A big irresponsibility, I just feel suspicious about every expression and equation in that book" and "I am confused." Regarding using textbooks with errors, it was found that 81.4% of them had negative views and stated their views about using these books such as "I do not rely on the textbook", "I can just look for another reference book" and "I cannot carry that textbook with me anymore." In the same study, the pre-service teachers (58.7%) stated that due to

physics textbooks containing errors, they felt less enthusiastic about studying physics course. It was identified in the research studies (Arons, 1981; Champagne, Gunstone and Klopfer, 1983; Berg and Brouwer, 1991; Yıldız, 2003) that misconceptions may occur in all age groups, resistance to change is encountered, misconceptions can impede students' learning of physics topics, and one of the reasons for misconceptions is the errors that textbooks involve.

An expression involved in a physics textbook (Fishbane, Gasiorowicz and Thornton, 2008, p. 9), which is usually suggested by instructors to students studying in science, engineering, and teaching undergraduate programs at universities to benefit from and which is used internationally draws attention. The expression that is considered for the discussion states, "All quantities can be converted into length, time and mass units in the end. No matter how complex any physical quantity is, it is stated as algebraic combination of these three basic quantities." It is anticipated that this expression will reinforce the retention of existing misconceptions on fundamental dimensions, dimensional analysis, and principles of dimensional analysis and its implementations; and it will also cause new misconceptions on dimensional analysis among many undergraduate students who use this physics textbook which includes that incorrect statement in their courses. With fundamental dimensions of length, mass, and time, only quantities related to mechanics can be identified or derived because length, mass, and time compose the set of basic dimensions (LMT) that only quantities related to mechanics can be presented and derived (Yıldız, 2015).

The Purpose of the Study

This research study was carried out to discuss a wrong statement written about dimensional analysis in a textbook, its use and effects and to describe it again. The physics textbook is prepared for the students who are studying in science, engineering, and teaching undergraduate programs at universities and who have to take compulsory physics courses.

Method

The data of this qualitative study on discussion and description of a wrong statement written about dimensional analysis in a physics textbook were gathered through examination of the documents such as book or scientific paper published on the subject. The findings of a qualitative study are usually composed of the data collected from interviews, observation and documents (Merriam, 2013). Document analysis can be used as data collection method in qualitative research. Document analysis consists of analysis of written materials that contain information about the cases or phenomena to be studied (Yıldırım and Şimşek, 2011). Some participants might be uncomfortable with the presence of the researcher or with the equipment used for recording during the interviews carried out to collect data. However, there is no such disadvantage for documents. Examining the documents is a way preferred rather than observations and interview, as it does not take a lot of time to reach and they are cheap and easy. Each book, journal and article in a library is a ready source of knowledge and data for a skilled and creative researcher (Merriam, 2013). A document analysis consists of five stages: access to the documents, control of their authenticity, understanding the documents, analysis of the data and the use of the data (Forster, 1995; as cited in Yıldırım and Şimşek, 2011).

Official records (birth, marriage, death, records of various organizations and programs, court decisions, notarial documents and contracts), written documents such as letters, diaries, memories, life stories, novels, poems, inscriptions, enactments, meeting records, development records, newspapers, articles, journals and books and visuals such as pictures, slides, films, videos, stamps, clothing, tools and equipment are commonly considered as documents (Sönmez and Alacapınar, 2011; Yıldırım and Şimşek, 2011; Merriam, 2013; Ekiz, 2013). As

stated by the researchers (Yıldırım and Şimşek, 2011), any documents which are reviewed by the experts in the field, controlled for their originality and arranged and organized (columns, textbooks, organizational documents, annual reports, scientific study reports, articles and etc.) can be a source of data, and using these documents can increase the reliability and validity of the research study.

In the study, the books and the scientific studies involving the topics of fundamental dimensions, principles and implementations of dimensional analysis within the framework of dimensional analysis were examined with regard to descriptive analysis method.

Findings and Interpretation

When documents regarding dimensional analysis (Ertaş, 1984; Koca, 1998; Bueche and Jerde, 2003; Çengel ve Cimbala, 2008; Yıldız, 2015) are examined, it is found that seven fundamental quantities (dimensions) are described to express all quantities in engineering and scientific disciplines (physics, chemistry) and all other quantities are derived from these seven fundamental quantities. According to the studies (Koca, 1998; Bueche and Jerde, 2003; Yıldız, 2015), the seven base dimensions consist of length, mass, time, electric current, temperature, amount of substance (number of moles) and luminous intensity, respectively (LMTAΘNC). Based on the documents analysed (Koca, 1998; Çengel and Cimbala, 2008), Yıldız (2015) stated that quantities regarding only mechanics could be described or derived with fundamental dimensions of length, mass, and time. In other words, Yıldız emphasised that fundamental dimensions of length, mass, and time composed the base dimensions (LMT), which expressed or derived quantities regarding mechanics. According to the same study, if base dimension of temperature is included in length, mass, and time, base dimensions which express or derive quantities regarding fluid mechanics (LMTΘ) emerge; if electric current is included in length, mass, and time, base dimensions which express or derive quantities regarding electricity and magnetism (LMTA) are composed. In the same study, if temperature is included in length, mass, time and electric current, base dimensions that express or derive quantities regarding thermodynamic (LMTAΘ) are obtained. If amount of substance is included in length, mass, time and electric current, base dimensions that express or derive quantities regarding the scientific disciplines of atomic and molecular physics (LMTAN) are obtained.

The wrong expression involved in a physics textbook (Fishbane, Gasiorowicz and Thornton, 2008, p. 9) which is usually suggested by instructors to students studying in science, engineering, and teaching undergraduate programs at universities to benefit from and is commonly used all around the world states that "All quantities can be converted into length, time and mass units in the end. No matter how complex any physical quantity is, it is stated as algebraic combination of these three basic quantities." It is required that this wrong expression, which is the subject of the research study, must be limited to mechanics. All quantities related to mechanics can be written with or derived from fundamental dimensions of length, mass, and time that compose the base dimensions (LMT) regarding mechanics. However, basic dimensions of length, mass, and time are inadequate to express or derive a quantity belonging to fluid mechanics, thermodynamic, atomic and molecular physics, and magnetism. Work (w) is a scalar quantity related to mechanics and electric potential (ΔV) is a scalar quantity regarding electricity and magnetism. The discussion can become more comprehensible when these two quantities belonging to different scientific disciplines are written in terms of fundamental dimensions.

Work done by a constant force is defined as scalar product or dot product of force vector ($\mathbf{F}$) and displacement vector ($\Delta\mathbf{x}$). If the force and displacement are in the same

direction, the work done by the constant force is only equal to the magnitude of the force and displacement product ($\cos 0^0 = 1$) (Yıldız, 2015).

$$\text{Work} = w = \mathbf{F}.\Delta\mathbf{x} = F\,\Delta x \cos 0^0 = F\,\Delta x$$
$$[w] = MLT^{-2}L \rightarrow [w] = ML^2T^{-2} = ML^2/T^2$$

Electric potential (ΔV) is defined as the energy per unit charge or the work done ($\Delta V = w/q$, $q = i\,\Delta t$) (Yıldız, 2015).

$$[\Delta V] = ML^2T^{-2}/\,AT = ML^2A^{-1}T^{-3} = ML^2/\,AT^3$$

As it is seen, although work is expressed in terms of length, mass, and time (ML^2/T^2), this is not possible for electric potential ($ML^2/\,AT^3$) so electric current (A) as a fundamental dimension has to be involved in the equation. Therefore, the wrong expression can be limited to mechanics rather than being general or inclusive and it can be written correctly and more clearly.

"In mechanics, the dimension of any physical quantity can be expressed as base dimensions length, time, and mass in the end. No matter how complex any physical quantity related to mechanics is, it can be described as algebraic combination of these three base dimensions. " The expression which had a distracting and inclusive feature at the beginning is re-formulated and only limited to mechanics. Moreover, the re-formulation of the expression, which is the subject of the study, can hinder the formation of misconceptions about dimensional analysis.

In the study conducted by Yildiz (2013), the errors pre-service teachers encountered in the textbooks they used in physics courses and their views about the use of these books filled with errors drew attention. 62.6% of the pre-service teachers stated that they had negative views about the mistakes in physics textbooks such as "a big irresponsibility", "I just feel suspicious about every expression and equation in that book", and "I am confused". Moreover, it was revealed that the same population of the study had negative views (81.4%) about the use of these books filled with errors such as "I do not rely on the textbook", "I can just look for another reference book", and "I cannot carry that textbook with me anymore. In addition, the pre-service teachers (58.7%) in the same study stated that these physics textbooks filled with errors had negative effects on their desire to study.

It was implied in the documents analysed (Arons, 1981; Champagne, Gunstone and Klopfer, 1983; Berg and Brouwer, 1991; Yıldız, 2003; Yildiz, 2013) that one of the sources of misconceptions is the textbooks that are full of errors and flaws and students learn misconceptions from these books. It will be beneficial to stick to the stages determined and to examine the examples used in the study conducted by Yıldız (2015) in order to understand the dimensional analysis easily without any misconceptions.

Conclusion

The research study has some important findings: a wrong statement written about dimensional analysis in a text book (Fishbane, Gasiorowicz and Thornton, 2008, p. 9) used for physics courses by the students studying in science, engineering, and teaching undergraduate programs at universities will not only be the only error in the textbook, it will cause misconceptions, and it can hinder learning dimensional analysis correctly and students' studying physics, and also other topics of physics.

The population of the study conducted by Yildiz (2013) consisted of students (total 75 students, 28 males, 47 females) studying in primary school mathematics teaching programme in the Faculty of education. In this study, more than half of the pre-service teachers (58.7%) stated that physics textbooks consisting of wrong equations, definitions, and diagrams discouraged them to study physics and this finding verifies that the errors in the books are not only a book error. Here, attention must be drawn on an interesting situation. Authors write books in their areas of expertise to help students or individuals. Moreover, they write books so that they can enable students to learn these topics more easily and better. However, considering the practices, if textbooks written or developed for students to learn physics more easily include some errors, they can prevent students from studying and learning physics.

As stated by Yildiz (2013), it is important that writers who develop the textbooks, publishers and the interpreters who are going to translate them into another language should stay away from all commercial concerns; they must be patient and should implement all steps that need to be taken to publish the book. It is a must that the person who is going to translate the book must have a command of the original language of the book and the major. It may not be enough for a person to know, write and speak both the original language of the book and the language into which the book will be translated very well. If the book that will be translated is about physics and the person who knows, speaks and writes both languages very well is not a physicist, he may not know the differences between the concepts of velocity and speed. Therefore, this condition will most probably cause the person to translate the book incorrectly and incompletely. In many documents, the definition for constant c ($c=3.10^8$ m/s), the speed of light in vacuum, is given as "the velocity of light spread in vacuum" (Yıldız, 2014). This wrong definition is the proof of the truth that is intended to say.

Discussion

The research studies (Arons, 1981; Champagne, Gunstone and Klopfer, 1983; Berg and Brouwer, 1991; Yıldız, 2003; Yıldız and Büyükkasap, 2006; Yildiz, 2013) reveal that books that are not written correctly both visually and conceptually can cause misconceptions among individuals. It is known that identifying and eliminating misconceptions takes time, requires extra work, and has effects that prevent students from learning physics topics and thus making the learning process difficult. Moreover, it is important that more attention must be paid while identifying misconceptions particularly about physics in science courses. Every opinion/idea, which is not true and different from scientific knowledge and scientists, must be evaluated as a misconception because for an idea to be considered as a misconception, it must contain three conditions consecutively (Eryılmaz and Sürmeli, 2002; Yıldız and Büyükkasap, 2006). The first one is that a person does not answer or write the question correctly. The second condition is that a person makes or writes an explanation about the incorrect answer, in other words, he must make a claim about it, and finally, he must be sure about the answer or explanation that is given or written. These three conditions must be fulfilled so that misconceptions can be distinguished from predictions, lack of knowledge and errors, and they can be identified because it is considered that students' lack of content knowledge in science courses, particularly in physics, is generally more than the other courses such as literature, geography and history.

The research study conducted by Yıldız (2015) explains how to teach or tell dimensional analysis in seven steps and uses lecturing method in learning to write. It can be beneficial to take into account the approach suggested in the study and to examine it. Moreover, it is required that instructors/faculty members who are teaching physics courses at the universities must mention the wrong expressions, equations and diagrams which they use

about the topics or which exist in the textbooks that students benefit from. Moreover, they must pay strict attention to share their corrected versions with the students.

References

Arons, A. (1981). Thinking, reasoning and understanding in introductory physics courses. Physics Teacher, 166-172.

Bean, T.W., Searles D., Singer H. & Cowen S., (1990). Learning Concepts from Biology Text through Pictorial Analogical Study Guide. *Journal of Educational Research*, 83 (4), 233-237.

Berg, T. & Brouwer, W. (1991). Teacher awareness of student alternate conceptions about rotational motion and gravity. *Journal of Research in Science Teaching*, 28(1), 3-18, Canada.

Bueche, F. J. & Jerde, D. A. (2003). Fizik ilkeleri-I (Çev. Ed.: K. Çolakoğlu), Düzeltilmiş ikinci Türkçe Baskı. Ankara: Palme Yayıncılık.

Champagne, A., Gunstone, R. & Klopfer, L. (1983). Naive knowledge and science learning. Research in Science and Technological Education, 1 (2), 173-183.

Çengel, Y. & Cimbala, J. M. (2008). Akışkanlar mekaniği. Birinci baskıdan çeviri (Çev. Ed.: Tahsin Engin), İzmir Güven Kitapevi: İzmir.

Ekiz, D. (2013). *Bilimsel Araştırma Yöntemleri*. Ankara: Anı Yayıncılık.

Ertaş, İ. (1984). Denel fizik dersleri, Cilt 1, Dördüncü baskı. İzmir: Barış Yayınları.

Eryılmaz, A., Sürmeli, E. (2002). Üç-Aşamalı sorularla öğrencilerin ısı ve sıcaklık konularındaki kavram yanılgılarının ölçülmesi. V. Ulusal Fen Bilimleri ve Matematik Eğitim Kongresi, 16-18 Eylül, ODTÜ, Ankara.

Fishbane, P. M., Gasiorowicz, S. & Thornton, S. T. (2008). Temel Fizik, Cilt 1, Üçüncü baskı (Çev. Ed.: Ü. Türkoğulları). Ankara: Arkadaş Yayinevi.

Koca, M. (1998). Akışkanlar mekaniği (242 s).Ankara: Palme Yayıncılık

Lord, M. (2001). Know Much About Science Books? Many Are Rife With Errors, Says New Study. U.S. News and World Report, 130 (3), 50-50.

Merriam, S. B. (2013). *Nitel Araştırma: Desen ve uygulama için bir rehber* (Çev. Ed.: S. Turan). Ankara: Nobel Akademik Yayıncılık Eğitim Danışmanlık Tic. Lmt. Şti.

Özay, E. ve Hasenekoğlu, İ. (2007). Some problems in visual presentation of biology-3 textbooks. Journal of Turkish Science Education, 4(1), 80-91.

Reid, D., (1990). The Role of Pictures In Learning Biology: Part 1, Perception and Observation. *Journal of Biological Education*, 24 (3), 161-172.

Sönmez, V. ve Alacapınar, F. G. (2011). *Örneklendirilmiş bilimsel araştırma yöntemleri*. Ankara: Anı Yayıncılık.

Ünsal, Y. ve Güneş, B. (2004). Bir kitap inceleme çalışması örneği olarak MEB lise 1. sınıf fizik ders kitabının eleştirel olarak incelenmesi. Gazi Üniversitesi, Türk Eğitim Bilimleri Dergisi, 2(3); 305-321.

Yıldırım, A. ve Şimşek, H. (2011). *Sosyal Bilimlerde Nitel Araştırma Yöntemleri*. Ankara: Seçkin Yayıncılık.

Yıldız, A. (2003). The ideas of students of physics about gravity, force and motion and the conjecture of the teaching staff regarding students' ideas, Master's thesis, Atatürk University School of Natural and Applied Sciences, Erzurum.

Yıldız, A. ve Büyükkasap, E. (2006). Misconceptions of the students in the department of physics about force and motion subjects and the conjecture of the teaching staff on this matter. *H.U. Journal of Education, 30, 268-277.*

Yildiz, A. (2013). Views of pre-service teachers related to the mistakes encountered in the textbooks which they benefited from in physics courses. International Journal of Academic Research Part B, Social Sciences and Humanities, 5(4), 406-411. Doi: 10.7813/2075-4124.2013/5-4/B.59

Yıldız, A. (2014). Views of pre-service teachers on speed constant "c=3.10^8 m/s". *The Journal of Academic Social Science Studies*, 28 Autumn II, 13-21. Doi:10.9761/JASSS2474

Yıldız, A. (2015). Dimensional analysis and its instruction. E-Journal of New World Sciences Academy, 10 (2), 100-112. Doi: 10.12739/NWSA.2015.10.2.1C0635