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Research Article

Opinions of Physics Teachers on the Teaching of Physical Constants

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Abstract
The aim of the study is to reveal physics teachers' views on constants in teaching physics subjects that include physical constants. The phenomenology approach, one of the qualitative research designs, was used in the study. The study group consists of a total of 10 physics teachers, 2 female and 8 male, working in five public high schools in two central districts of a province with metropolitan status in the east of Turkey. Data were collected using an opinion form containing three open-ended questions about physical constants prepared by the researcher. Descriptive analysis method was used to organize the data. Taking into account the similarities of the written answers, they were grouped under certain categories. The grouped answers of physics teachers, the number of men and women who wrote the answers and the total number of participants were transferred to the relevant tables prepared separately for each question. In addition, semi-structured interviews were held with 5 volunteers and free time participants among the 10 physics teachers who made up the study group. The opinions expressed by the participants in the interviews were examined and 4 opinions that were considered important and interesting were given verbatim in the findings section. Physics teachers' answers (60.0%) such as "No explanation is given because they are constants" and "Explanations are made as written in the reference books and their numerical values are given exactly" support the claim that physical constants are not taken into consideration in the teaching process.

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Fizik Öğretmenlerinin Fiziksel Sabitlerin Öğretimi Hakkında Görüşleri

Anahtar Kelimeler
Fiziksel sabitler, fizik öğretmenlerinin görüşleri, fenomenoloji.

Özet
Çalışmanın amacı, fizik öğretmenlerinin fiziksel sabitleri içeren fizik konularının öğretiminde sabitlerle ilgili görüşlerini ortaya çıkarmaktır. Çalışmada nitel araştırma desenlerinden fenomenoloji yaklaşımı kullanılmıştır. Çalışma grubunu, Türkiye'nin doğusunda büyükşehir statüsünde olan bir ilin iki merkez ilçesinde bulunan beş devlet lisesinde görev yapan 2'si kadın ve 8'i erkek olmak üzere toplam 10 fizik öğretmeni oluşturmaktadır. Veriler, araştırmacı tarafından fiziksel sabitler hakkında hazırlanan üç açık uçlu sorunun bulunduğu bir görüş formu kullanılarak toplanmıştır. Verilerin düzenlenmesi için betimsel analiz yöntemi kullanılmıştır. Yazılan cevapların benzerlikleri dikkate alınarak belli kategoriler altında toplanmıştır. Fizik öğretmenlerinin gruplandırılan cevapları, cevapları yazan kadın, erkek ve toplam katılımcı sayıları her soru için ayrı hazırlanan ilgili tablolara aktarılmıştır. Ayrıca çalışma grubunu oluşturan 10 fizik öğretmeni arasından gönüllü ve zamanı müsait olan 5 katılımcı ile yarı yapılandırılmış görüşmeler yapılmıştır. Mülakatlarda katılımcılar tarafından ortaya konulan görüşler incelenerek önemli ve ilginç olduğu düşünülen 4 görüş bulgular kısmında aynen verilmiştir. Fizik öğretmenlerinin "Sabit oldukları için herhangi bir açıklama yapılmıyor", "Kaynak kitaplarda yazıldığı gibi açıklama yapılıyor ve sayısal değerleri aynen veriliyor" şeklinde yazdıkları cevaplar (60.0%), fiziksel sabitlerin öğretim sürecinde önemsenmedikleri iddiasını desteklemektedir.

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1. Introduction

There are many universal constants encountered in physics subjects, such as the gravitational constant, Coulomb constant, vacuum electrical permittivity, electron charge, proton mass, Avogadro constant, speed of light in a vacuum, Planck constant, and Boltzmann constant (Giancoli, 2021; Gribbin, 2015; Halliday, Resnick & Walker, 2014; Mazur, 2016; Mazur, 2022; Serway & Beichner, 2010; Young, Adams, & Chastain, 2015; Young, Freedman & Ford, 2010; Zettili, 2022). It is stated that the teaching of physics subjects should focus on the main ideas that form the conceptual basis of the subject in a way that can answer students' questions. As a result of this focus, the big picture should be built without resorting to equations and formulas (Mazur, 2015).

A study on the teaching of physical constants (*e, c, h, etc.*) (Yıldız, 2021) claimed that an easy and correct understanding of physical constants could be possible by providing three suggested conditions. 1) A physical constant should be considered a fundamental property or component of the subject, not just a numerical value that does not need to be memorized, should be considered within the subject's integrity, and its importance and function should be conceptually explained. 2) Generally, every physical constant may have a story of its emergence, like the biographies of scientists. Discussing this story when needed can support the constant's proper and deserved place in the students' minds. 3) It would be beneficial to write the numerical value of a physical constant in the decimal form immediately after its exponential representation, as written in physics books. The decimal representation of the numerical value of the physical constant, which is more suitable for the daily use of numbers, can lead students to make more meaningful and accurate inferences and understand their primary functions and the value of their magnitude.

The charge of the electron was measured as e=1.6x10^{-19} Coulomb by Robert Millikan and his colleagues through numerous experiments conducted between 1909 and 1917 (Bueche & Jerde, 2000; James, 2015). Generally, when two objects interact, one gives electrons, and the other takes electrons, with the object losing electrons becoming positively charged and the object gaining electrons becoming negatively charged. The exchange of electrons is the effective situation in charging objects with electrical charges. The positive charge is the electrical charge of the proton, while the negative charge is the electrical charge of the electron. The proton and electron have the same magnitude of electric charge (e=1.6x10^{-19} Coulomb). The electric charge of an electron is the smallest electric charge found in nature; hence, the electron charge is considered a "fundamental charge." The fact that electrical charge (Q) in nature is always found as whole multiples of the electron charge (e) (Q = ne, n = 1, 2, 3, ...) is defined as the "quantization" of electrical charge (Serway & Beichner, 2002; Young, Freedman & Ford, 2010; Yıldız, 2016). In other words, the characteristic of the quantization of electrical charge is that the electrical charge (Q) on any object said to be charged with electrical charge is equal to the whole multiples (5e, 14e, 57e, 108e, ...) of the electron charge (e=1.6x10^{-19} C). It would be helpful to write the electron charge (e) at least once in decimal form as "e=0.00000000000000000016 C" after giving it in exponential form within the natural flow of the "electric charge and properties" topic (Yıldız, 2021). Additionally, it should be noted that there is no need to memorize the value of any physical constant.

The speed of light in a vacuum is c=3x10^{8} m/s. This value is the highest speed known, measured, and encountered in nature. No particle or object with such a high speed has been discovered yet. It is known that light consists of energy packets called photons, which are electromagnetic waves. Gamma rays (γ), X-rays, ultraviolet rays, visible light, infrared rays, microwaves, and radio waves are all electromagnetic waves, ordered from highest to lowest energy (Halliday, Resnick & Walker, 2015; Mazur, 2016). Each electromagnetic wave has different energy, frequency, and wavelength, but their speed in a vacuum is the same, equal to the constant "c." The speed of light in a vacuum, "c," is equal to the product of an electromagnetic wave's frequency (f) and wavelength (λ) (c=fλ). For a vacuum, the equality $f_{purple}\lambda_{purple} = f_x\lambda_x = f_\gamma\lambda_\gamma = c$ can be written. Thus, the product of an electromagnetic wave's frequency and wavelength is always constant, and this constant value is c=3x10^{8} m/s. Writing the speed of light in a vacuum as "c=300,000,000 m/s" immediately after giving it in exponential form could be more understandable and effective for students (Yıldız, 2021). This is because the latter representation is more consistent with how numbers are given or used daily. Banks do not give the amounts of money in customers' accounts in exponential form; they write them in decimal form.

Writing the value of Planck's constant as h=6.62x10^{-34} Joule·second immediately after giving it in exponential form as "h=0.000000000000000000000000000000000662 J·s" could draw attention since it would span an entire line on a slide or board. One can see how small a number it really is. Looking at the decimal value, students might ask, "Is Planck's constant (h) really this small?", "How can a constant with such a small numerical value have

such an effective function?", and ponder the answers. Multiplying the frequency of an electromagnetic wave (light) by the value "*h*=0.00000000000000000000000000000000662 J·s" calculates the energy of that electromagnetic wave (E=*h*f). In other words, the energy of a photon emitted from a light source is calculated using "*h*." Seeing and thinking that it is easy to calculate the energy of an electromagnetic wave using Planck's constant can lead to a better understanding of the function of the constant (*h*) (Yıldız, 2021). Additionally, as stated in a study (Yıldız, 2015), it should be noted that Planck's constant is an indispensable variable in quantum physics, appearing in many equations, equalities, and explanations during the development and progress of quantum physics.

Decimal representation is introduced earlier than exponential representation when considering the learning process of numbers. As stated in a document (Rancière, 2015), individuals can achieve more permanent learning at ages closer to the period when they learn their native language. Therefore, displaying the numerical value of a physical constant in decimal form, rather than exponential form, can lead students to make more meaningful and accurate inferences and understand its main function (Yıldız, 2021). It is anticipated that physics teachers have significant opinions on how explanations about constants and their numerical values should be provided in teaching physics topics involving universal constants (*e, c, h, etc.*).

Purpose of The Study

The aim of the study is to reveal the opinions of physics teachers on the explanations of constants and the presentation of their numerical values in the teaching of physics topics containing physical constants.

2. Method

2.1. Research Design

In this study, a phenomenology study approach, one of the qualitative research designs, has been used. In phenomenology research, data sources are generally individuals or groups who have experienced the phenomenon under investigation and can express or reflect it (Yıldırım & Şimşek, 2018).

2.2. Study Group

As in many qualitative studies, purposeful sampling methods are used in phenomenological studies (Yıldırım & Şimşek, 2018). In this study, criterion sampling, one of the purposeful sampling types, was used to reveal the opinions of physics teachers about teaching physical constants and any strategies they may have. The main criterion in criterion sampling is that the selected cases, groups, or participants are rich in terms of providing information. This is because the information obtained can be used to detect and improve any existing shortcomings or disruptions (Patton, 2014).

The study group consists of a total of 10 physics teachers, 2 female and 8 male, working at five public high schools in the central districts of a metropolitan province in eastern Turkey. The average ages for the participating women and men

were 50 and 49, respectively, while the average professional seniority was determined as 26 and 24 years, respectively.

2.3. Data Collection

In this study, an interview form consisting of three open-ended questions about physical constants, prepared by the researcher, was used as a data collection tool. As stated in a study (Büyüköztürk et al., 2013), the opinions of experts in the field were taken to support the content validity of open-ended questions. In addition, necessary corrections were made in line with the feedback received from experts to ensure the comprehensibility of the open-ended questions in the interview form. The researcher stated that the sincere answers of the participants to the open-ended questions in the interview form could provide very important data for their research and were therefore valuable. In other words, by expressing the need for the ideas and explanations of physics teachers regarding the teaching of physical constants, the researcher tried to minimize the obstacles to the data flow.

In phenomenological research, repeated interviews increase the validity and reliability of the study by providing the researcher with the opportunity to confirm the explanations and meanings reached with the interviewed persons (Yıldırım & Şimşek, 2018). In this context, semi-structured interviews were conducted with five participants who volunteered and had available time regarding their answers to the three questions. No device that recorded images or sounds was used during the interview process. The expressions and explanations recorded in writing by the researcher during the interviews were used to determine the participant's opinions. After each face-to-face interview, the written opinions and thoughts were reviewed, and any missing or incorrect written expressions were immediately confirmed, and necessary adjustments were made. Four interesting opinions from the views of the five interviewed participants have been presented exactly under the relevant heading in the findings section.

2.4. Data Analysis

Description forms the basis of all qualitative research reports. The best advice for researchers is to read the collected data repeatedly. The more the data is examined, the more patterns and categories become visible to the researcher (Patton, 2014). Based on this claim, the descriptive analysis method was used to organize the obtained data. In the descriptive analysis method, the data is brought together in a meaningful and logical way, organized, and described understandably (Yıldırım & Şimşek, 2018). Subsequently, the necessary inferences are made, and the findings are interpreted.

In this study, the written answers of physics teachers for each open-ended question were examined in detail. Considering the similarities of the written answers, they were gathered under certain categories. The grouped answers of physics teachers were transferred to the relevant tables prepared separately for each question, considering the number of female, male, and total participants who wrote the answers. Inferences and comments on the grouped expressions of the participant physics teachers were provided after each table. The created categories were reviewed again, and the grouped expressions with common and similar meanings were recombined.

In the semi-structured interviews conducted with physics teachers, four interesting opinions were selected from the views of the five participants determined based on the expressions and explanations recorded in writing by the researcher and have been presented exactly under a separate subheading in the findings section.

3. Findings

Question 1. How are explanations and numerical values given in teaching physics topics involving universal constants (e, c, h, etc.)? Please write.

Table 1. Physics teachers' written answers to the question, "How are explanations and numerical values given in the teaching of physics topics involving universal constants?"

Physics teachers' answers	Female	Male	f
No explanation is given since they are constants	-	1	1
Explanations are given as written in the source books and numerical values are written as is	1	4	5
Explanations are given as stated in the source books, and numerical values are written in both exponential and decimal forms	-	3	3
Additional explanations are provided to those given in the source books, and numerical values are written in both exponential and decimal forms	1	-	1
Total	2	8	10

Table 1 presents the answers written by physics teachers for the first question. The answer "No explanation is given since they are constants" in the first row actually implies that physical constants are not valued. The answer "Explanations are given as written in the source books and numerical values are written as is," written by half of the participants, supports the notion that teaching physical constants is not given enough importance. This is because physical constants are generally only in sourcebooks (Giancoli, 2021; Gribbin, 2015; Halliday, Resnick & Walker, 2014; Mazur, 2016; Mazur, 2022; Serway & Beichner, 2010; Young, Freedman & Ford, 2010; Zettili, 2022) provided in exponential form. In the last two answers, the participants' (40.0%) thought that "Numerical values of physical constants are written in both exponential and decimal forms" supports Yıldız's (2021) claim that "After a physical constant's numerical value is written in exponential form, it should be written in decimal form at least once."

Question 2. In your opinion, how should explanations and numerical values of constants be given in teaching physics topics containing universal constants? Please write.

Table 2. Answers written by physics teachers for the question "In your opinion, how should explanations and numerical values of constants be given in teaching physics topics containing universal constants?"

Physics teachers' answers	Female	Male	f
Explanations should be given as stated in the source books, and numerical values should be written in both exponential and decimal forms	-	1	1
I support adding to the explanations given in the source books and writing numerical values in both exponential and decimal forms	1	1	2
In addition to what is stated in the source books, if physical constants have an origin story, it should be mentioned; for proper understanding and creating a lasting impact in learners' minds, it would be appropriate to write numerical values in the decimal form at least once	1	6	7
Total	2	8	10

When Table 2 is examined, it can be seen that the relative opinions of physics teachers on the teaching of physical constants are given in three categories. The answer in the third row shows that 70.0% of the participants have more detailed thoughts about teaching physical constants. The views put forward by the participants with these three different answers show similarities with the claims mentioned in the second and third conditions of Yıldız's (2021) study on the teaching of physical constants.

Question 3. In your opinion, what kind of difficulties are experienced in the teaching of physics topics containing universal constants (e, c, h, etc.)? Please write.

Table 3. Answers written by physics teachers for the question, "In your opinion, what kind of difficulties are experienced in the teaching of physics topics containing universal constants?"

Physics teachers' answers	Female	Male	f
Students solve problems and questions without using the numerical values of physical constants. Since the symbols of physical constants are used in questions and formulas, no difficulties are encountered	1	3	4
No difficulties are experienced	-	2	2
Generally, since exam questions are based on interpretation, students do not care about physical constants and no problems are encountered	-	1	1
Writing the numerical values of physical constants can sometimes be problematic. The length of the decimal forms, not fitting in a certain space, creates trouble. Errors are observed when written in exponential form. Therefore, symbols should be used instead of numerical values	1	1	2
Operations related to physical constants can sometimes be difficult because they generally require advanced physics and mathematics knowledge	-	1	1
Total	2	8	10

The first three respondents (70.0%) stated that there were generally no difficulties. The statement "Calculation with symbols of physical constants in questions and formulas" written by 40.0% of the participants, and the statement "Exam questions are based on interpretation" written by 20.0%, are consistent reasons for the answer "no difficulty". Reasons such as "The decimal values of the constants are long" and "It requires advanced knowledge of physics and mathematics" were given for the difficulties encountered. Physics teachers expressed difficulties in teaching physical constants at a rate of 30.0%.

Views Presented By Physics Teachers During The Interviews

Semi-structured interviews were conducted with five volunteers who had available time among the 10 physics teachers who formed the study group. The views presented by the participants in the interviews conducted with half of the study group were examined, and four views that were considered important and interesting are presented below as they were:

> *It would be more efficient for students to determine the numerical values of physical constants through experiments.*
>
> *Physical constants do not seem very convincing to students, so their existence is not considered important.*
>
> *In teaching physics topics involving physical constants, calculations are not made with the numerical values of the constants. This is because they are not included in the learning outcomes.*
>
> *High school physics questions are generally conceptual and based on interpretation. Instead of using the numerical values of the constants in solving problems, the symbols given in the formulas are used. In this way, solutions to the problems are carried out, including the symbols of the constants, without the need for the numerical values of the constants in calculations.*

4. Conclusion and Discussion

The first question of the study was prepared to reveal the current understanding, practice, and attitude towards constants in the teaching of physics topics involving physical constants. The answers "No explanation is made because they are constant" and "Explanation is made as written in the source books and numerical values are written exactly" (60.0%) written by physics teachers for the first question support this claim. It can be said that constants are not given much importance in teaching physics topics involving physical constants. The current practices do not seem to be in line with the idea that constants should be accepted as a fundamental component of the related subject, as stated in Yıldız's (2021) study.

The second question was asked to investigate the relative ideas, expected practices, and attitudes of physics teachers about teaching physics topics involving physical constants. The views presented by participants with three different answers for the second question show similarities with the claims expressed in the second and third conditions suggested by Yıldız (2021) in his study about teaching

physical constants. The answers to the second question show that participants (70.0%) express their thoughts in more detail about teaching physical constants. The opinion that "If physical constants have an emergence story, it should definitely be mentioned, and to ensure proper understanding and create a lasting impact on the learners' minds, their numerical values should be written at least once in decimal form" written by 70.0% of participants is important. However, in the documents examined (Giancoli, 2021; Gribbin, 2015; Halliday, Resnick & Walker, 2014; Mazur, 2016; Mazur, 2022; Serway & Beichner, 2010; Young, Adams, & Chastain, 2015; Young, Freedman & Ford, 2010; Zettili, 2022) it is seen that only the numerical values of the physical constants written in the form of exponential expressions are included.

The classification of the relative answers written by physics teachers for the third question reveals the opinion that there is no difficulty in teaching physical constants at a rate of 70.0%. In the interviews conducted with half of the study group, participants expressed views that can be summarized as "the existence of constants is not given much importance", "questions are generally of a conceptual nature", and "calculations are not made with the numerical values of physical constants, instead, the symbols in the formulas are used". The findings obtained from the interviews support the statements previously written by the participants in the opinion form.

References

Bueche, F. J., & Jerde, D. A. (2000). *Principles of physics-2* (K. Çolakoğlu, Trans. Ed. 6th ed.). Palme.

Büyüköztürk, Ş., Kılıç-Çakmak, E., Akgün, Ö. E., Karadeniz, Ş., & Demirel, F. (2013). *Bilimsel araştırma yöntemleri / Scientific research methods* (Geliştirilmiş 14. baskı). Pegem.

Giancoli, D. C. (2021). *Physics for scientists and engineers* (5th Edition). Pearson.

Gribbin, J. (2015). *Q is for quantum: an encyclopedia of particle physics*. CreateSpace Independent Publishing Platform.

Halliday, D., Resnick, R., & Walker, J. (2014). *Fundamentals of physics-2* (B. Akınoğlu & M. Alev, Trans. 9th ed.). Palme.

Halliday, D., Resnick, R., & Walker, J. (2015). *Fundamentals of physics-3* (B. Akınoğlu & M. Alev, Trans. 9th ed.). Palme.

James, I. (2015). *Remarkable physicists from Galileo to Yukawa* (S. Erduman, Trans.), 2. Basım. Türkiye İş Bankası Kültür Yayınları.

Mazur, E. (2015). *Principles and practice physics-1* (A. Verçin & A. U. Yılmazer, Trans. Ed.). Nobel.

Mazur, E. (2016). *Principles and practice of physics-2* (A. Verçin & A. U. Yılmazer, Trans. Ed.). Nobel.

Mazur, E. (2022). *Principles & practice of physics* (Second Edition). Pearson.

Patton, M. Q. (2014). *Qualitative research & evaluation methods*. (M. Bütün & S. B. Demir, Tras. Eds.). Pegem.

Rancière, J. (2015). *Cahil hoca* (S. Kılıç, Trans.). Metis.

Serway, R. A., & Beichner, R. J. (2010). *Physics for scientits and engineers with modern physics-1* (K. Çolakoğlu, Trans. Ed. 5th ed.). Palme.

Serway, R. A., & Beichner, R. J. (2002). *Physics for scientits and engineers with modern physics-2* (K. Çolakoğlu, Trans. Ed. 5th ed.). Palme.

Yıldırım, A., & Şimşek, H. (2018). *Sosyal bilimlerde nitel araştırma yöntemleri* (11. baskı). Seçkin.

Yıldız, A. (2021). Discussion on teaching physical constants / Fiziksel sabitlerin öğretiminin tartışılması. *The Journal of Kesit Academy*, *7*(27), 378-385. http://dx.doi.org/10.29228/kesit.51026

Yıldız, A. (2016). Discussion on the prospective teachers' understanding level of electric charge. *The Turkish Online Journal of Educational Technology*, Special Issue for INTE 2016, 731-736.

Yıldız, A. (2015). Planck's constant and its significance for quantum physics / Planck sabiti ve kuantum fiziği için önemi. *Akademik Sosyal Araştırmalar Dergisi*, *3*(19), 56-62. http://dx.doi.org/10.16992/ASOS.872

Young, H. D., Adams, P. W., & Chastain, R. J. (2015). *Sears & Zemansky's college physics* (Tenth Edition). Pearson.

Young, H. D., Freedman, R. A., & Ford, A. L. (2010). *Sears and Zemansk's university physics with modern physics*,12th Edition (H. Ünlü, Trans. Ed. 12th ed.). Pearson.

Zettili, N. (2022). *Quantum Mechanics: Concepts and Applications* (Third Edition). Wiley.