Investigation of students' knowledge of physical quantities' symbol, unit and formula

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Contents

Abstract

The usage of symbol, unit and formula of some fundamental physical quantities are quite important for science and engineering students regardless of their majors. The purpose of the present research was to examine the students' knowledge regarding the usage of symbol, unit, and formula of the fundamental physical quantities. The opinions of students on using symbol, unit, and formula of the fundamental physical quantities were also investigated. The research was conducted with 220 college students. The data of the research were collected by using an evaluation form (data sheet) and an essay. The data sheet was designed for investigating the students' knowledge about symbol, unit, and formula of twenty eight fundamental physical quantities. The volunteer students' opinions about the essential keys (symbol, unit, and formula) of the fundamental physical quantities were also collected by means of the essay. The descriptive statistical analyses of the collected data with help of the data sheet were analyzed. The results presented that approximately 30% of the students could determine the symbol and unit of the fundamental physical quantities besides 25% of the students could write the formula of the fundamental physical quantities. These findings revealed that the many students did not understand the importance of the symbol, unit, and formula of the fundamental physical quantities by problem solving. According to the student essays, many students thought that the usage of fundamental physical quantities' symbol, unit, and formula was not necessary to solve qualitative and quantitative problems therefore they did not any motive to understand the fundamental concepts by using the fundamental physical quantities' symbol, unit, and formula. Some recommendations in the light of the findings of the present research were presented.

Keywords: formula, physics, symbol, unit

Introduction

Alternative educational methods instead of traditional educational methods were developed in order to better contribute the physics learning of students. Some alternative educational methods (e.g., Concepts of Physics (Zollman, 1990), Interactive Lecture Demonstrations (Sokoloff & Thornton, 1997), Modeling Physics (Wells, Hestenes & Swackhamer, 1995), Peer Instruction (Mazur, 1997), Physics by Inquiry (McDermott, 1996), Problem Solving Strategies in Physics (Gok, 2015), Problem-based Learning in Physics (Duch, 1996), Problem Solving (Heller, Keith, & Anderson, 1992), Socratic Dialog Laboratories (Hake, 1992), Studio Physics (Wilson, 1994), STEM-Science, Technology, Engineering, and Mathematics (Freeman, et al., 2014), Tutorials in Physics (McDermott & Shaffer, 1998), Workshop Physics (Laws, 1991) were examined the different categories (e.g., conceptual learning, problem solving, problem-based learning, project-based learning, inquiry-based learning, etc. The purpose of developed alternative educational methods was to enhance students' academic performance (Adam, et al., 2006; Domert, Airey, Linder, & Kung, 2007; Gok & Gok, 2017; Gok, 2018; Lising & Elby, 2004; May & Etkina, 2002; Redish, Saul & Steinberg, 1998).

The relationships between symbol, unit, and formula of the fundamental physical quantities in science and engineering education play an important role by problem solving. If the students do not sufficiently comprehend essential keys (symbol, unit, and formula), they could not solve quantitative and qualitative problems. Generally the students do not effectively make connections between symbol, unit, and formula of the fundamental physical quantities according to given and described problem situations and they only focus on finding the result of the problem by doing four operations instead of using the essential keys therefore they may have great difficulty in problem solving (Gok, 2016; Gok & Gok, 2016). "To be a successful physics student it is often enough to be able to identify the physics quantities in the formula and know how to use the formula to solve physics problems" (Domert, et al., 2007, p.26). Consequently, the students should be taught how to solve quantitative and qualitative problems and where to use symbol, unit, and formula of the fundamental physical quantities. Besides the instructor should put more emphasis on conceptual learning based on the fundamental physical quantities.

Most instructors do not usually explain to the students dimensional analysis, scalar and vector quantities in Turkey. They believe that the teaching of dimensional analysis and scalar and vector quantities is a waste of time. If the dimensional analysis, and scalar and vector quantities are explained to the students in detail, they may understand the importance of essential keys of the fundamental physical quantities (Gok, 2015; Gok, 2016). The instructors also do not use the scientific language based on international standards (Taylor & Thompson, 2008) for demonstrating the symbol and unit of the fundamental physical quantities. Some examples could be presented as follows: the majority of instructors use "d" symbol for demonstrating distance, some instructors use "d" symbol for indicating mass density instead of presenting with "ρ". On the other hand, many instructors use "G" symbol for showing weight instead of presenting with "W", etc.

The usage of the difference notation could be caused some drawbacks (misconceptions, misunderstanding, misinterpretation, etc.) on students' understanding therefore many students could not easily make connections between previously learned essential keys and essential keys they are learning in their physics courses (Gok, 2016; Gunes, Akdag, & Gunes, 2016; Keles, Ertas, Uzun, & Cansız, 2010). Consequently the instructors should use a common scientific language and explain to students the importance of the essential keys.

There is not enough research in the open literature regarding the usage of the symbol, unit, and formula of the fundamental physical quantities and gauging knowledge of students' symbol, unit, and formula. Some studies (Gok, 2016; Rozier & Viennot, 1991; Sherin, 2001, Steinberg, Wittman, & Redish 1997) merely examined the importance of the fundamental physical quantities. More studies are needed in this field.

The purpose of the present research was to examine the students’ knowledge concerning the fundamental physical quantities' symbol, unit, and formula. The investigated research questions were as follows:

1. What is the students’ knowledge related to the fundamental physical quantities' symbol and unit?

2. What is the students’ knowledge related to the fundamental physical quantities' formula?
3. What is the students' opinions related to the fundamental physical quantities' symbol, unit, and formula?

Method

The research was performed on four departments offering two-year programs (Industrial Glass and Ceramics, Geotechnic, Drilling Technology, Natural Building Stone Technology) in Torbali Technical Vocational School of Higher Education at Dokuz Eylul University, Turkey. The students enrolled in these departments were basically trained in the engineering field. The study sample consisted of 220 college students whose ages were between 18 and 20.

The present research was used survey methodology. The data of the research were collected by using an evaluation form and an essay. The evaluation form "data sheet" was designed for investigating the students' knowledge about symbol, unit, and formula of twenty eight fundamental physical quantities. Therefore the validity and reliability of the data sheet could not be analyzed in the present study. The data sheet was consisted of two sections. In the first section, the symbols and unit symbols of the some fundamental physical quantities in SI (International System of Units) were given to the students. The students were asked for finding the concept and unit names of the fundamental physical quantities. In the second section, the formulas of the fundamental physical quantities were only given to the students. The students were asked for finding the concept names of the fundamental physical quantities. The same fundamental physical quantities were asked in the sections. 15 of 28 fundamental physical quantities cover Physics I and the others contain Physics II. The students were given to approximately twenty minutes in order to fill out the data sheet. The fundamental physical quantities were chosen from Physics and Engineers for Scientists with Modern Physics (Tipler & Mosca, 2008). The fundamental physical quantities which the students frequently meet were selected from the textbook.

Students' opinions were also collected and documented by writing an anonymous essay on the usage of symbol, unit, and formula of the fundamental physical quantities (What are you thinking about the usage of symbol, unit, and formula of fundamental physical quantities?). 30 volunteer students only wrote the essay. No interactions among the students were allowed during the writing session, which took about 15 minutes to complete. The opinions of the students were read, coded, and categorized as being positive or negative. The opinions of the students were separated into two categories. The first category including seven items was named as cognitive opinion and the second category covering nine items was named as affective opinion.

Results

Table 1, Table 2, and Table 3 present the descriptive statistics related to the students' knowledge on the symbol, unit, and formula of the fundamental physical quantities. The data obtained from the data sheet are generally indicated that the students do not comprehend the symbol, unit, and formula of the fundamental physical quantities by solving problems concerning classical mechanics, and electricity and magnetism. The results of the research are presented as follows:

- Roughly 20% of the students answered the symbol and unit of the mass density while 50% of the students could not respond the symbol and unit of mass density.
- Almost 15% of the students defined the symbol and unit of the pressure. 80% of the students could not write the formula of the pressure.
- 80% of the students determined the symbol and unit of the force. Approximately 45% of the students could not write the formula of the force based on Newton's Laws of Motion.
- Roughly 65% of the students could not give any answer the symbol and unit of the torque.
- Approximately 60% of the students did not describe the symbol and unit of the weight.
- 50% of students indicated the symbol and unit of the velocity and acceleration.
- Approximately 85% of the students could not define the symbol, unit and formula of the angular velocity and the angular acceleration.
- Almost 30% of the students identified the symbol and unit of the work. 70% of the students could not write the formula of the work.
- Roughly 70% of the students could not indicate the symbol, unit, and formula of the heat.
- 20% of the students showed the symbol and unit of the power while 70% of the students could not write the formula of the power.
- Approximately 70% of the students could not describe the symbol, unit, and formula of the impulse.
- Nearly 80% of the students could not determine the symbol, unit, and formula of the momentum.
- Almost all students did not determine the symbol, unit, and formula of the angular momentum.
- Roughly 75% of the students responded the symbol, unit, and formula of the electric field strength.
- Nearly 90% of the students could not determine the symbol, unit, and formula of the electric flux and electric flux density.

- Many students described the symbol, unit, and formula of the electric potential, capacitance, electric current, and resistance.
- Almost 50% of the students could not determine the symbol, unit, and formula of the current density.
- Nearly 25% of the students described the symbol and unit of the magnetic flux density while 90% of the students could not write the formula of the magnetic flux density.
- Roughly 70% of the students could not define the symbol, unit, and formula of the magnetic flux.
- Many students did not determine the symbol, unit, and formula of the magnetic dipole moment, magnetization, and inductance.

Table 1: The Descriptive Analysis of Student Responses Related to Some Fundamental Physical Quantities' Symbol and Name for Physics I

Physical Quantities		SI Derived Units		Correct		Incorrect		No Answer	
Quantity Name	**Quantity Symbol***	**Name in SI**	**Symbol in SI**	**N**	**%**	**N**	**%**	**N**	**%**
Mass Density	ρ	kilogram per	kg/m^3	51	23.2	55	25.0	114	51.8
Pressure	P	pascal	Pa	37	16.8	58	26.6	125	56.8
Force	$\boldsymbol{F}$	newton	N	171	77.7	2	0.9	47	21.4
Torque	$\boldsymbol{\tau}$	newton	Nm	47	21.4	27	12.3	146	66.4
Weight	$\boldsymbol{w}$	kilogram	N	61	27.7	31	14.1	128	58.2
Velocity	$\boldsymbol{v}$	meter per	m/s	116	52.7	22	10.0	82	37.3
Acceleration	$\boldsymbol{a}$	meter per	m/s2	120	54.5	10	4.5	90	40.9
Angular	$\boldsymbol{w}$	radian per	rad/s	16	7.3	21	9.5	183	83.2
Angular	α	radian per	rad/s2	11	5.0	18	8.1	191	86.8
Work	W	joule	J	68	30.9	49	22.3	103	46.8
Heat	Q	joule	J	47	21.4	16	7.3	157	71.4
Power	P	watt	W	43	19.5	64	29.1	113	51.4
Impulse	$\boldsymbol{I}$	newton	Ns	20	9.1	55	25.0	145	65.9
Momentum	$\boldsymbol{p}$	kilogram	kgm/s	10	4.5	37	16.8	173	78.6
Angular	L	kilogram	kgm2/s	0	0	11	5.0	209	95.0

Note: *The vectors are indicated in bold. 15 fundamental physical quantities were selected for Physics I.

Table 2: The Descriptive Analysis of Student Responses Related to Some Fundamental Physical Quantities' Symbol and Name for Physics II

Physical Quantities		SI Derived Units		Correct		Incorrect		No Answer	
Quantity Name	Quantity Symbol*	Name in SI	Symbol in SI	N	%	N	%	N	%
Electric Field	$\boldsymbol{E}$	volt per	V/m	167	75.9	14	6.36	39	17.7
Electric Flux	ϕ	newton	Nm^2/C	7	3.18	13	5.91	200	90.1
Electric Flux	$\boldsymbol{D}$	coulomb	C/A^2	0	0	9	4.1	211	95.9
Electric	V	volt	V	163	74.1	7	3.18	50	22.7
Capacitance	C	farad	F	175	79.5	20	9.1	25	11.3
Electric	I	ampere	A	180	81.8	29	13.1	11	5.0
Current	J	ampere per	A/m^2	83	37.7	18	8.18	119	54.1
Resistance	R	ohm	Ω	166	75.4	9	4.1	45	20.4
Magnetic Flux	$\boldsymbol{B}$	tesla	T	52	23.6	23	10.4	145	65.9
Magnetic Flux	ϕ_m	weber	Wb	35	15.9	24	10.9	161	73.1
Magnetic	$\boldsymbol{\mu}$	ampere per	A/m^2	3	1.36	18	8.18	199	90.4
Magnetization	**M**	ampere per	A/m	2	0.9	13	5.91	205	93.1
Inductance	L	henry	H	11	5.0	7	3.18	202	91.8

Note: *The vectors are indicated in bold. 13 fundamental physical quantities were selected for Physics II.

SI units are divided into base and derived units. Base units consist of the meter, the kilogram, the second, the ampere, the kelvin, the mole, and the candela (Taylor & Thompson, 2008). Derived units "are formed as products of powers of the base units according to the algebraic relations linking the quantities concerned" (Taylor, 2001, p. 3).

Table 3: The Descriptive Analysis of Student Responses Related to Some Fundamental Physical Quantities' Formula and Name for Physics I and II

Some Derived Fundamental Physical	Quantity	Correct		Incorrect		No Answer	
Quantity Name	Formula*	N	%	N	%	N	%
Mass Density	$\rho = m/V$	67	30.5	42	19.1	111	50.5
Pressure	$\boldsymbol{P} = \boldsymbol{F}/A$	23	10.4	21	9.5	176	80.0
Force	$\boldsymbol{F} = m\boldsymbol{a}$	84	38.2	34	15.5	102	46.4
Torque	$\boldsymbol{\tau} = \boldsymbol{F}d$	83	37.7	40	18.2	97	44.1
Weight	$\boldsymbol{w} = m\boldsymbol{g}$	83	37.7	57	25.9	80	36.4
Velocity	$\boldsymbol{v} = \Delta\boldsymbol{x}/\Delta t$	87	39.5	9	4.1	124	56.4
Acceleration	$\boldsymbol{a} = \Delta\boldsymbol{v}/\Delta t$	87	39.5	10	4.5	123	55.9

Angular Velocity	$\boldsymbol{w} = d\theta/dt$	18	8.2	14	6.4	188	85.5
Angular Acceleration	$\boldsymbol{\alpha} = d^2\theta/dt^2$	13	5.9	17	7.7	190	86.3
Work	$W = \boldsymbol{F}_x\Delta\boldsymbol{x}$	48	21.8	12	5.5	160	72.7
Heat	$Q = mc\Delta T$	31	14.1	22	10.0	167	75.9
Power	$P = W/t$	39	17.7	27	12.3	154	70.0
Impulse	$\boldsymbol{I} = \boldsymbol{F}\Delta t$	41	18.6	18	8.2	161	73.2
Momentum	$\boldsymbol{p} = m\boldsymbol{v}$	20	9.1	21	9.5	179	81.4
Angular Momentum	$\boldsymbol{L} = I\boldsymbol{w}$	0	0	0	0	220	100
Electric Field Strength	$\boldsymbol{E} = \boldsymbol{F}/q$	174	79.1	17	7.72	29	13.3
Electric Flux	$\emptyset = \int \boldsymbol{E}\hat{n}dA$	3	1.36	19	8.63	198	90
Electric Flux Density	$\boldsymbol{D} = \epsilon\boldsymbol{E}$	0	0	9	4.1	211	95.9
Electric Potential	$V = kq/r$	161	73.1	13	5.9	46	20.9
Capacitance	$C = q/V$	168	76.3	14	6.3	38	17.2
Electric Current	$I = \Delta Q/\Delta t$	189	85.9	17	7.72	14	6.36
Current Density	$J = I/A$	92	41.8	23	10.4	105	47.7
Resistance	$R = V/I$	173	78.6	11	5.0	36	16.3
Magnetic Flux Density	$\boldsymbol{B} = \mu\boldsymbol{H}$	5	2.27	15	6.81	200	90.1
Magnetic Flux	$\emptyset_m = \int \boldsymbol{B}\hat{\boldsymbol{n}}\, dA$	46	20.9	17	7.72	157	71.3
Magnetic Dipole Moment	$\boldsymbol{\mu} = NIA\hat{\boldsymbol{n}}$	0	0	24	10.9	196	89.1
Magnetization	$\boldsymbol{M} = d\boldsymbol{\mu}/dV$	2	0.9	15	6.81	203	92.2
Inductance	$L = \emptyset_m/I$	2	0.9	12	5.45	206	93.6

* The vectors are indicated in bold. The book of Tipler & Mosca (2008) was used for the formula of fundamental physical quantities.

Table 4 shows cognitive and affective opinion of the students on the symbol, unit, and formula of the fundamental physical quantities. The cognitive and affective opinion of the students were generally evaluated respectively, approximately 85% of the students thought in terms of the cognitive opinion of the students that the usage of symbol, unit, and formula of the fundamental physical quantities was not useful to solve quantitative and qualitative problems. The essential keys of the fundamental physical quantities did not help to enhance their problem solving skills. Besides they did not make an effort to learn the relationships between symbol and unit, and formula of the fundamental physical quantities. Many students believed in terms of the affective opinion of the students that the usage of the essential keys of the fundamental physical quantities was a waste of time, they did not want to solve the problems by using the essential keys, besides the essential keys do not make sense to learn the students.

Table 4. The cognitive and affective opinion of the students on the symbol, unit, and formula (S/U/F) of some fundamental physical quantities

	Positive		***Negative***	
Cognitive Opinion	**N**	**%**	**N**	**%**
It provides hints for problem solving.	8	26.67	22	73.33
It helps to connect among parameters.	4	13.33	26	86.67
It helps to recall the formula.	5	16.67	25	83.33
It facilitates to understand the physical concepts.	6	20.00	24	80.00
It makes a sense.	4	13.33	26	86.67
It helps to solve problems.	5	16.67	25	83.33
It helps to enhance problem solving skills.	3	10.00	27	90.00
Affective Opinion				
Students enjoy performing mathematical operations.	2	6.67	28	93.33
Students take pleasure in problem solving.	2	6.67	28	93.33
Students are interested in problem solving.	3	10.00	27	90.00
Students get bored with the usage of the essential keys.	26	86.67	4	13.33
Students use the essential keys in their daily lives.	2	6.67	28	93.33
Students like to deal with the essential keys.	2	6.67	28	93.33
Students feel comfortable with the usage of the essential keys.	4	13.33	26	86.67
Students think that the usage of the essential keys is a waste of time.	28	93.33	2	6.67
Students think that the usage of the essential keys is entertaining.	4	13.33	26	86.67

Conclusion

The results of the research were evaluated in two categories. One of the categories was classical mechanics "Physics I" and the other was electricity and magnetism "Physics II".

When the results of the research in terms of classical mechanics were analyzed, nearly 80% of the students described the symbol and unit of the force while 45% of the students could not write the formula of the force according to Newton' Laws of Motion. Many students did not determine the symbol, unit, and formula of angular velocity, angular acceleration, and angular momentum. When the results of the students were generally evaluated, approximately 25% of the students defined the symbol and unit of the fundamental physical quantities and 20% of the students also could write the formula of the fundamental physical quantities for Physics I.

When the results of the research in terms of electricity and magnetism were analyzed, many students identified the symbol, unit, and formula of the electric potential, capacitance, electric current, and resistance. Numerous students could not write the symbol, unit, and formula of the electric flux, electric flux density, magnetic dipole moment, magnetization and inductance. When the results of the students were generally evaluated, 37% of the students identified the symbol and unit of the fundamental physical quantities and 35% of the students could also write the formula of the fundamental physical quantities for Physics II. These ratios obtained from the data sheet are quite low for science, technology, engineering and mathematics education.

When the results of the first and second research questions were interpreted from technical aspect, the majority of the students had difficulty in determining the symbol and unit of the fundamental physical quantities and they did not usually make the connection between the symbol, unit, and formula of the fundamental physical quantities for Physics I and Physics II.

Some students could not answer the fundamental physical quantities' symbol, unit and formula which torque, heat, impulse, momentum, magnetic dipole, moment, magnetization, and inductance for classical mechanics. Some students had problems by indicating the symbol of the work, power, and impulse. Some students had also difficulty in understanding the differences between electric flux and electric flux density, between electric current and current density, between magnetic flux and magnetic flux density. The results of some studies (Close & Heron, 2011; Lopez, 2003; Mashood & Singh, 2012a; Mashood & Singh, 2012b; Mashood, 2014; Smaill & Rowe, 2012) were supported by the result of the present research.

Many students had difficulty in identifying the symbols of the fundamental physical quantities because the majority of instructors used different symbols for showing the same fundamental physical quantity in Turkey. Therefore some students referred as "d" the symbol of mass density while some students indicated as . They also faced with the similar problems for indicating of the other physical quantities' symbol (impulse "I", current "I"; momentum "p", pressure "P", power "P"; volume "V" electric potential "V"; magnetic flux density "B" and magnetic flux strength "H"). The results of some studies (Goris, 2016; Hekkenberg, 2012; Pablico, 2010; Rowlands, 1997; Smaill & Rowe, 2012) were supported by the findings of the present research. Many students did not remember the formula of fundamental physical quantities both classical mechanics and electricity and magnetism although the usage of symbol, unit and formula of the fundamental physical quantities (mass density, force, weight, electric current, electric potential, resistance, etc.) were taught to the students at every level of education.

The main reason of these problems might be low consciousness of students on using the units and symbols and/or absence of conceptual learning habits. When the indicated problems were generally evaluated, many students seemed reluctant to learn the symbol unit, and formula of the fundamental physical quantities; they preferred to memorize the formula of the physical quantities instead of comprehending the physical quantities; they focused on problem solving without determining the symbol and unit of the given or desired quantities; besides many instructors immediately solved the problems without performing dimensional analysis, showing vector and scalar quantities, explaining given concepts in the problems.

The cognitive and affective opinion of the students about the usage of the essential keys of the fundamental physical quantities were reported as follows: many students thought that the usage of the fundamental physical quantities' symbol, unit, and formula was not necessary to solve problems therefore they did not want to learn the concepts by using the essential keys of the fundamental physical quantities. They believed that the usage of fundamental physical quantities' symbol, unit, and formula was a waste of time by problem solving. On the other hand, several students believed that the usage of the essential keys of the fundamental physical quantities was helpful for problem solving.

Recommendation

Some suggestions based on the results of the research could be presented as follows: The instructors might use common scientific language for presenting of the symbol, unit, and formula of the fundamental physical quantities. They might teach the dimensional analysis and show vector and scalar quantities to the students. They might explain relationships between symbol, unit, and formula of fundamental physical quantities. Besides they might spend more time for conceptual learning. As a result of the presented recommendations, the students may begin to realize the big picture for meaningful learning.

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