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Teacher opinions about the conceptual challenges experienced in teaching physics curriculum topics

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Abstract

This study aimed to determine the teacher opinions about the conceptual challenges experienced in teaching the topics of the physics curriculum. Qualitative research methods were used in the study, which was conducted with 38 physics teachers teaching at 28 different Anatolian High Schools in Ankara during 2012 – 2013 spring and 2013 – 2014 fall semesters. The semi-structured teacher interview form developed by the researchers was used as the data collection tool. The form consisted of seven open-ended questions. The data obtained during the interviews were analyzed through the descriptive statistic method. As a result, teachers mentioned that students had difficulties in the conceptual understanding of motion, torque and simple harmonic motion in the "Force and Motion" unit, the particle nature of light and the wave nature of particles in the "Modern Physics" unit as well as variable current, capacitors, coils, transformers and electronic circuit elements in the "Electricity and Electronic" unit. It was concluded that the challenges that were experienced in general stemmed from various factors such as students' lack of knowledge in terms of concepts, existence of misconceptions, difficulties in comprehending abstract concepts, deficiencies in mathematical operations and insufficiency of time allocated to the course leading to incomplete teaching tasks.

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Keywords: Physics curriculum, conceptual challenge, teacher opinions, phsyics education.

1. Introduction

Physics is the field of science that is encountered at various locations in the universe as well as being related to the events that we use and observe in the universe and enabling individuals to find solutions for daily life events or

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analyze them from various perspectives. Since physics has such an essential role in the universe, the importance of physics courses, which are taught and applied effectively at schools, has increased significantly (Aycan, Aycan, Genç, & Özkaya, 2000). Physics education enables students to attain the required skills for scientific thinking, producing knowledge, keeping track of developing technological changes, understanding and interpreting the events occurring in the nature (Arslan & Eraslan, 2003). Students attend physics classes under the impression of their previous knowledge, attitudes, beliefs and values. This leads them to have opinions and prejudices that involve incomplete or scientifically inaccurate thoughts. These false or incomplete assumptions may continue in students throughout their educational lives. On the other hand, students may also generate scientifically inaccurate opinions within the teaching process. These factors make conceptual learning and teaching of physics even more challenging (Jonassen, 1994; Treagust, Duit, & Fraser, 1996). Studies on physics education have shown that such reasons as low level of interest and motivation about physics classes, inability to attribute meanings to abstract concepts, misusage or inaccurate usage of concepts related to scientific thoughts and beliefs, false usage of concepts related to the models and theories as well as the previous thoughts and beliefs are the main reasons that make concepts difficult to learn (Hoffmann, 1990; Duit, 1992; Sencar & Eryılmaz, 2002; Eryılmaz & Tatlı, 2000). Within this scope, this research has been designed to study the factors that hinder learning of concepts included in the physics curriculum.

Education system has an essential role in effective physics teaching. Today, various countries have implemented changes and innovations in their education systems to increase the level of development (Ünal, Coştu, & Karataş, 2004). One of these changes is the revision, modification or organization of the curriculum (Ayas, Çepni, & Akdeniz, 1993). Since 2004, there have been attempts to revise, modify or organize the curriculum in Turkey based on the constructivist learning theory (Göçen & Kabaran, 2013). The curricula aim to ensure that students attain knowledge and skills that address the aims of the education program in an organized way (Varış, 1996). The aim of the physics curriculum, which has been revised in Turkey recently, is to improve scientific literacy in students as well as increasing the level of their interest in physics, motivating students towards inquiry, using scientific knowledge and methods to explain an event and creating awareness about the nature of science (Ministry of National Education [MONE], 2013). In the light of this aim, secondary school physics curriculum was developed in 2007 when the high school education period was extended to four years and implemented gradually starting from the 2008 – 2009 academic year. Later on the curriculum was updated in 2011. The Physics Curriculum (PC), which was developed in 2007 and updated in 2011, was implemented to Grades 9, 10, 11 and 12 in two hours per week as a main course. However, for students that choose Physics as an elective course in Grades 10, 11 and 12, the allocation of hours per week is 3 for students whose Grade 10, 4 for Grade 11 and 3 for Grade 12. The number of attainments changes for students who choose Physics as an elective course and for those who do not. The topics and concepts/terms that are included in the curriculum for both options mentioned before are displayed in Table 1 and Table 1.1.

Table 1. The topics of Physics Curriculum that was developed in 2007 and revised in 2011

Grade 9	Grade 10	Grade 11	Grade 12
UNIT 1: NATURE OF SCIENCE Fields of Physics, Nature of Physics, Importance of Modeling and mathematics in Physics, Physics in Our Daily Life and Technology	UNIT 1: MATTER AND ITS PROPERTIES Solids, liquids, gases and plasma	UNIT 1: MATTER AND ITS PROPERTIES Pressure in Solids, Liquids and Gases, Heat Exchange in Solids, Liquids and Gases	UNIT 1: MATTER AND ITS PROPERTIES Thermodynamic, Change of state
UNIT 2: MATTER AND ITS PROPERTIES Classification and Properties of Matter, States of Matter	UNIT 2: FORCE AND MOTION The reason for motion, the motion of the object where net force is zero, the motion of an object under the influence of a certain force, a reaction created by an action	UNIT 2: FORCE AND MOTION Short-term interactions of the objects, Rotational motion and its causes, The motion of an object rotating under the influence of a net force, The motion of an object rotating where net torque is zero, The motion of a movement where net force and net torque are zero, The force that holds the solar system together, Work and Energy	UNIT 2: FORCE AND MOTION Simple harmonic motion
UNIT 3: FORCE AND MOTION Motion at a Single Dimension, Basic Forces in the Nature, Newton's Laws of Motion, Friction Force	UNIT 3: ELECTRICITY Electric charges, electrical force and field, current in electrical circuits, voltage and electrical power	UNIT 3: MAGNETISM Magnetic field and sources of magnetic field, Electromagnetic induction	UNIT 3: ELECTRICITY AND ELECTRONIC Variable current and direct current, Capacitors, Bobbins, Transformers and Elements of Electronic Circuit
UNIT 4: ENERGY Work, power and energy, energy conversion and the conservation of energy, energy resources, heat and temperature	UNIT 4: MODERN PHYSICS Modern Physics, Special relativity	UNIT 4: MODERN PHYSICS Particle theory of light, Matter waves, Structure of an atom	UNIT 4: WAVES Reflection of light, Refraction of light, Thin and thick lenses, Colours , Electromagnetic waves, Wave nature of light
UNIT 5: ELECTRICITY AND MAGNETISM Electric current, magnetic effect of electric current	UNIT 5: WAVES Waves on a coil spring, water waves	UNIT 5: WAVES Sound waves, illumination	UNIT 5: MODERN PHYSICS X-rays, Structure of matter, Structure of nucleus, Radioactivity, Nuclear energy
UNIT 6: WAVES Fundamental concepts about waves		UNIT 6: ASTROPHYSICS Stars, Classification of stars, Stellar processes and stellar evolution, Galaxies and the expanding universe, Cosmology	UNIT 6: ELEMENTARY PARTICLES Particles, antiparticles and photons, Classification of particles, Quarks; the building block of the baryons and mesons
			UNIT 7: REALM OF PHYSICS Realm of physics

Table 1.1. The concepts/terms of Physics Curriculum that was developed in 2007 and revised in 2011

Grade 9	Grade 10	Grade 11	Grade 12
UNIT 1: NATURE OF SCIENCE *Concepts/Terms:* Observation, Scalar and Vector Quantities, Measurement and Uncertainty UNIT 2: MATTER AND ITS PROPERTIES *Concepts/terms:* Mass, Volume, Density, Common and Distinguishing Properties of Matters, Chemical and Physical Changes, Natural Radioactive Elements UNIT 3: FORCE AND MOTION *Concepts/terms:* Position, Displacement, Speed, Velocity Inertia, Action – Reaction Forces, Friction Forces UNIT 4: ENERGY *Concepts/terms:* Work, Power, Energy, Mechanical Energy (potential and kinetic energy), Energy Conversions and Conservation of Energy, Productivity, Energy Resources, Renewable and Non-Renewable Resources UNIT 5: ELECTRICITY AND MAGNETISM *Concepts/terms:* Electric current, potential difference, resistance, magnetic effect of an electric current UNIT 6: WAVES *Concepts/terms*: Vibration, Wave, Wavelength, Frequency, Period, Wave motion speed, amplitude, cross wave, longitudinal wave, mechanic wave, electromagnetic wave	UNIT 1: MATTER AND ITS PROPERTIES *Concepts/terms:* Enlargement or minimization at a certain rate, adhesion and cohesion, Surface tension, Capillarity, Plasma UNIT 2: FORCE AND MOTION *Concepts/terms:* Net force, Average speed, Instantaneous speed, Relative motion, Range UNIT 3: ELECTRICITY *Concepts/Terms:* Electric charge, Electrical force, Electrical field, Electric potential, Electrical potential energy, Electric current, Electromotor force, Power in Electrical Circuits UNIT 4: MODERN PHYSICS *Concepts/terms:* Modern Physics, Inertial Reference System, Invariance of speed of Light according to the speed of the observer and resource in Inertial Reference System, Invariance of Laws of Physics, Special relativity and results of the relativity UNIT 5: WAVES *Concepts/terms:* Discharge, Extension, Reflection, Discharge of Composition, Wave Crest, Wave Trough, Interference, Standing Wave, Nodal Point, Abdominal Point, Fundamental Frequency, Harmonics, Refraction, Diffraction	UNIT 1: MATTER AND ITS PROPERTIES *Concepts/terms:* Pressure in Solids, hydrostatic pressure and buoyancy force, the relationship between fluid velocity and pressure in hydraulics, expansion and contraction in solids, liquids and gases UNIT 2: FORCE AND MOTION *Concepts/Terms:* Linear Velocity, Angular Velocity, centripetal acceleration, torque, impulse, linear momentum, stable equilibrium, unstable equilibrium, center of gravity, center of mass, gravitational field, flexibility, potential energy, gravitational force UNIT 3: MAGNETISM *Concepts/terms:* Magnetic field, magnetic power, magnetic pole, magnetic permeability, magnetic flux, induction UNIT 4: MODERN PHYSICS *Concepts/terms:* Blackbody radiation, Planck Constant, Photoelectric effect, Compton effect, Particle theory of light, Matter waves (de Broglie hypothesis), properties of electron, Rutherford process and Bohr atomic model, Structure of an atom, Laser light UNIT 5: WAVES *Concepts/terms:* Ultrasonic, infrasonic, Doppler effect, supersonic, shock wave, sonic boom, diffraction of sound waves, natural frequency, resonance, interference of sound waves, beat, beat frequency, light beam, light ray, transparent substance, semitransparent substance, opaque substance, shadow, sharpness, light intensity, light flux, luminance intensity, light pressure UNIT 6: ASTROPHYSICS *Concepts/Terms:* Stars, Star clusters, Brightness, Radiation power, supernova, black and white dwarfs, neutron stars, black holes, galaxies, quasars, cosmic background radiation, big bang	UNIT 1: MATTER AND ITS PROPERTIES *Concepts/terms:* Thermal balance, heat dissipation, heat exchange, the effect of pressure on state changes UNIT 2: FORCE AND MOTION *Concepts/terms:* Simple harmonic motion, restoring force UNIT 3: ELECTRICITY AND ELECTRONIC *Concepts/terms:* Variable current, direct current, capability, Electrical permittivity, dielectic, performance of transformer UNIT 4: WAVES *Concepts/terms:* Diffuse and regular reflection, Plane mirror, laws of reflection, Visible region, Concave and convex mirrors, Radius of curvature, Refraction of light, Index of refraction, Snell law, Apparent depth, Dispersion of light, Total reflection, Critical angle, Thin lenses, Myopia, hypermetropia, astigmatism, Diopter of lens, Angular magnification, Aberration of lenses, Color, Transparent materials, Opaque objects, Colored filters, Primary and secondary colors, Additive colorization, Electromagnetic spectrum, Electromagnetic waves, Doppler effect, Polarization, Diffraction of light, Huygens principle, Resolving power, Bright and dark fringes, Interference of light UNIT 5: MODERN PHYSICS *Concepts/terms:* X-rays, Structure of matter, Structure of nucleus, Radioactivity, Nuclear energy UNIT 6: ELEMENTARY PARTICLES *Concepts/terms:* Particles and antiparticles, Hadrons, Leptons, Baryons, Mesons, Quarks and opposite quarks UNIT 7: REALM OF PHYSICS *Concepts/terms:* Hypothesis, law, theory

In 2013, Physics curriculum was revised and decided to be implemented gradually starting from Grade 9 in the 2013-2014 academic year. The New Physics Curriculum (NPC), which was decided to be implemented gradually starting from the 2013-2014 academic year, was planned to be taught to Grades 9 and 10 two hours per week and the 4 hours per week was decided to be allocated for Grades 11 and 12 (Table 2, Table 2.1). One of the major differences between the PC and NPC is that the PC is based on the spiral structure; however the NPC is not (MONE, 2007).

Table 2. The topics of the secondary school physics curriculum that was revised in 2013

Grade 9	Grade 10	Grade 11	Grade 12
UNIT 1: INTRODUCTION TO PHYSICAL SCIENCE Introduction to physical science	1. UNIT: PRESSURE AND BUOYANCY FORCE Pressure and Buoyancy Power	UNIT 1: FORCE AND MOTION Vectors, Relative Motion, Newton's Laws of Motion, Motion That is Constant in One Dimension, Motion in Two Dimensions, Energy and Motion, Impulse and Linear Momentum, Torque, Balance	1. UNIT: REGULAR CIRCULAR MOVEMENT Regular Circular Movement, Circular Shift Movement, Angular Momentum, Gravitation and Kepler's Laws
2. UNIT: MATTER AND ITS FEATURES Matter and Density, Solids, Fluids, Plasmas	2. UNIT: ELECTRICITY AND MAGNETISM Electric Charges, Current, Potential Difference, Resistance, Electrical Circuits, The Relationship Between Current and Magnetic	2. UNIT: ELECTRICITY AND MAGNETISM Electrical Force and Electric Field, Electrical Potential, Regular Electrical Field and Capacity, Magnetism and Electromagnetic Inductance, Alternating Current, Transformers	UNIT 2: SIMPLE HARMONIC MOTION Simple harmonic motion
3. UNIT: KUVVET VE HAREKET Motion in One Dimension, Force, Newton's Laws of Motion	3. UNIT: WAVES Key Variables of Wave and Wave Motion, Water Waves, Sound Waves, Earthquake Waves and Features of Waves		3. UNIT: WAVE MECHANICS Diffraction in Waves, Interference and Doppler Effect, Electromagnetic Wave
4. UNIT: ENERGY Work, Power and Energy, Mechanical Energy, Conservation of Energy and Energy Conversion, Efficiency, Energy Resources	4. UNIT: OPTICAL Enlightenment, Shadow, Reflection, Plane Mirrors, Global Mirrors, Refraction, Color, Prisms, Lenses, Eye and Optical Instruments		4. UNIT: INTRODUCTION TO ATOMIC PHYSICS AND RADIOACTIVITY Historical Development of the Concept of Atom, Big Bang and Formation of the Universe, Radioactivity
5. UNIT: HEAT AND TEMPERATURE Heat, Temperature and Internal Energy, Changes of States, Thermal Balance, Energy Transmission Ways and Energy Transmission Speed, Expansion			UNIT 5: MODERN PHYSICS Special relativity, Introduction to quantum physics, Photoelectric effect, Compton and De Broglie
			6. UNIT: APPLICATIONS OF MODERN PHYSICS IN PHYSICS Imaging Technologies, Semiconductor Technology, Superconductors, Nanotechnology, X-Ray, Laser Beams, Scientific Research Centers

Table 2.1. The concepts/terms of the secondary school physics curriculum that was revised in 2013

Grade 9	Grade 10	Grade 11	Grade 12
UNIT 1: INTRODUCTION TO PHYSICAL SCIENCE *Concepts/terms:* Science, Observation, Experiment, Measurement, Modeling, Unit systems, Scalar and vector quantity 2. UNIT: MATTER AND ITS FEATURES *Concepts/Terms:* Mass, Volume, Density, Durability, Adhesion, Cohesion, Surface Tension, Capillarity 3. UNIT: KUVVET VE HAREKET *Concepts/Terms:* Location, The way taken, displacement, speed, instantaneous speed, average speed, acceleration, force, frictional force, inertia, action-reaction forces 4. UNIT: ENERGY *Concepts/Terms*: Work, power, energy, kinetic energy, potential energy, mechanical energy, conservation of energy, energy conversion, energy transfer, efficiency, renewable energy, nonrenewable energy 5. UNIT: HEAT AND TEMPERATURE *Concepts/Terms:* Heat, temperature, internal energy, specific heat, heat capacity, change of state, thermal stability, energy transmission speed, expansion	1. UNIT: PRESSURE AND BUOYANCY FORCE *Concepts/Terms:* Bernoulli's Principle, Pressure in Solids, Pressure in Fluids, Buoyancy Power, Archimedes' principle 2. UNIT: ELECTRICITY AND MAGNETISM *Concepts/Terms:* Charge, Conductor, Electrical Field, Current, Electrical Potential Difference, Resistance, Ohm's Law, Joule Law, Magnetic field 3. UNIT: WAVES *Concepts/Terms:* Wave, Vibration, Amplitude, Wavelength, Speed, Frequency, Period, Resonance 4. UNIT: OPTICAL *Concepts/Terms:* Enlightenment, Light Intensity, Luminous Flux, Shadow, Reflection, Refractive index, Snell's law, Full Reflection, Limiting Angle, Visible Depth	UNIT 1: FORCE AND MOTION *Concepts/Terms:* Vector, energy, relative motion, acceleration, free fall, limiting speed, impulse, momentum, conservation of momentum, torque, balance, center of mass, center of gravity 2. UNIT: ELECTRICITY AND MAGNETISM *Concepts/Terms:* Electrical Force, electrical field, capacity, capacitors, alternating current, inductance, impedance, capacitance, resonance, magnetic field, magnetic flux, induction current, the efficiency of transformer	1. UNIT: REGULAR CIRCULAR MOVEMENT *Concepts/Terms:* Linear Velocity, Angular Velocity, Centripetal Acceleration, Angular momentum UNIT 2: SIMPLE HARMONIC MOTION *Concepts/terms*: Displacement, amplitude, restoring force, equilibrium point 3. UNIT: WAVE MECHANICS *Concepts/Terms:* Interference, diffraction, Doppler effect, electromagnetic waves 4. UNIT: INTRODUCTION TO ATOMIC PHYSICS AND RADIOACTIVITY *Concepts/Terms:* Atom, Bohr's Atomic Theory, Energy Levels, Stimulation, Big Bang, Sub-particle, anti-matter, radioactivity, fission, fusion UNIT 5: MODERN PHYSICS *Concepts/terms:* Special relativity, Blackbody radiation, Photoelectric effect, Compton effect, De Broglie hypothesis 6. UNIT: APPLICATIONS OF MODERN PHYSICS IN PHYSICS *Concepts/Terms:* Semiconductor, solar cell, LED's, diodes, transistors, superconductors, Nano-materials, x-ray, laser, stimulation, stimulated emission

Teachers, who are the inseparable elements of education as the implementers of the curriculum, are one of the most important factors ensuring qualified teaching and training of individuals who would contribute and guide the society (Karakuyu, 2008). With respect to the opportunities they are provided, teachers aim to ensure that students attain the targeted attainments in line with the aims of the curriculum (Budak, 1997). The education programs, which have been designed in this perspective, have become the major resources for the teachers as important actors of teaching (Yiğit, 2013). The problems or deficiencies of a program may be identified during its implementation; therefore, the opinions, criticism, recommendations and suggestions of teachers should be taken into account within the process (Sadi & Yıldız, 2012). Additionally, it has been reported that teachers, being in verbal or nonverbal communication with the students throughout the learning process, have an essential role qualified to make judgments about learning and learning process through observing and understanding the thoughts and emotions of students within the classroom (Şişman, 2000). In the light of all these reasons, it is believed this study on the teacher opinions about the conceptual challenges experienced regarding the topics of the physics curriculum, which was developed in 2007, revised in 2007 and 2011, would contribute to the literature due to the lack of sufficient research on the new physics curriculum in particular.

2. Method

This study, where the teacher opinions were taken about the conceptual challenges experienced in teaching the topics in the physics curriculum, the qualitative research methods were used.

2.1. Sampling

This study was participated by 38 physics teachers teaching Grades 9, 10, 11 and 12 at 28 Anatolian High Schools in Ankara during the 2012 – 2013 spring and 2013 – 2014 fall semesters. There were teachers among the participants that taught more than one grade level. For each grade level, 20 teachers were asked for their opinions. The participants were determined according to the criterion sampling method, which is one of the purposive sampling methods. Criterion sampling methods was preferred due to the fact that the study required the opinions of individuals that have certain levels of knowledge and experience in a subject area (Ersoy, 2013). Within this scope, teachers were expected to express their opinions about the classes they were teaching during the course of the study.

2.2. Data collection tools

In order to be used as the data collection tool, a semi-structured teacher interview form with seven open-ended questions was developed by the researchers. The questions were created upon the analysis on the PC and NPC. During the development of the interview form, three physics education experts were asked for their opinions and the questions were formulated accordingly. Before the interview form was finalized, a pilot study was conducted with four physics teachers and the questions in the form were revised in such a way to address the research problem. As a result of these evaluations, the final version of the interview form, which would reveal the conceptual challenges experienced in teaching the topics in physics curriculum.

2.3. Application of data collection tools

The semi-structured interviews with physics teachers were made in the environments appropriate to the teachers. Each interview lasted about 25 – 30 minutes. The interviews were audio recorded and transcribed in the electronic environment for further analysis. Each opinion expressed by the teachers for the questions were recorded in separate files in the electronic environment.

2.4. Analysis of data

For the analysis of the data obtained as a result of the semi-structured interviews, descriptive statistic method was used. It has been reported that in semi-structured interviews, the categories should not be determined before the data are obtained (Yin, 1984). As Yin suggested (1984), categories were created based on the similarities or oppositions of the responses given to the questions by the physics teachers. At the initial stage of the data analysis, the files that the data were saved in were reviewed and categories were determined to fit for each response. Next, the categorized data were classified within themselves. And at the final stage, the findings of the study were obtained upon categorization of the data that were found to be similar after classification. Furthermore, the responses provided by the physics teachers for the questions were cited in order to support the findings of the study.

3. Findings

The findings obtained at the end of the analysis indicated that there were topics, in which the students experienced conceptual challenges at each grade level and that these challenges stemmed from the lack of conceptual knowledge, existence of misconceptions, difficulty that students had in understanding abstract concepts, lack of mathematical operational skills and insufficiency of the time allocated to the course. With respect to the NPC teachers were observed to mention that the content of the curriculum was more simplified than the previous one, there were less restrictions imposed on teachers for teaching the curriculum content, the program was not in conformity with the university placement test and the existing textbooks did not comply with the curriculum. Similarly, it was found that teachers expected potential conceptual challenges due to the factors such as the sequence of the topics presented and the insufficiency of the time allocated to the course hours. The seven questions that the physics teachers were expected to answer with the aim of determining the conceptual challenges experienced in teaching physics curriculum topics are presented hereby below along with the findings obtained as a result of the analysis.

"Among the topics of the physics curriculum, what are the most challenging topics for students in terms of conceptual learning?" was the first question asked to the physics teachers. The findings obtained from the semi-structured interviews made with participating teachers indicated that motion as a part of the "Force and Motion" unit in Grade 9, current, voltage and electrical power in electrical circuits at the "Electricity" unit in Grade 10, torque an the "Modern Physics" unit in Grade 11 as well as the simple harmonic motion in the "Force and Motion" unit and variable current, capacitors, coils, transformers and electronic circuit elements at the "Electricity and Electronic" unit in Grade 12 were most challenging topics and concepts for students in terms of conceptual learning (see Table 3).

During the semi-structured interviews, teachers expressed the reasons for the conceptual learning challenges that the students experienced using the following statements (T: Teacher; #: Number of teacher):

T5: *"Students lack the sufficient knowledge about derivatives and integral in mathematics; therefore, they cannot comprehend the formula or do the operations. The problems occurring due to the lack of knowledge in mathematical operations are generally experienced in the 'Force and Motion' unit."*

T23: *"RLC circuits and transformers at the 'Electricity and Electronics' Unit and the simple harmonic motion at the 'Force and Motion' in Grade 12 do not comply with the content of the university placement test. The first phase of the university placement test that is administered in March does not contain relevant questions; however the topics are presented in the fall semester according to the curriculum. Students, who focus on the university placement test do not study the topics of Grade 12 that are not in the scope of the university placement test and therefore they have difficulties in learning these topics."*

T30: *"'Waves' unit is quite comprehensive and challenging; however, it is taught in Grade 12 and due to the stress experienced by students with respect to the upcoming university placement test, students have difficulties in attributing meanings to the topic".*

T31: *"Students have difficulty in understanding topics that contain abstract concepts such as the 'Modern Physics' unit."*

According to the semi-structured interviews made with the teachers, the lack of students' ability to do the mathematical operations, intensity of the abstract topics and the noncompliance with the university placement test content were the main reasons for the conceptual challenges that students experienced.

Table 3. The most challenging units and topics for students to learn

UNITS	SUBJECTS	GRADE 9 Number of Teachers (%)	GRADE 10 Number of Teachers (%)	GRADE 11 Number of Teachers (%)	GRADE 12 Number of Teachers (%)
Force and Motion					
	Motion	10 (50%)	6 (30%)	-	-
	Torque	-	-	9 (45%)	-
	Simple Harmonic Motion	-	-	-	8 (40%)
Electricity and Magnetism					
	Resistance	5(25%)	-	-	-
	Current in Electric Circuits, Voltage and Electrical Power	-	7 (35%)	-	-
	Magnetic Field and Sources of Magnetic Field Electromagnetic induction	-	-	8 (40%)	-
Waves					
	Mechanic Waves, Electromagnetic Waves	2 (10%)	-	-	-
	Waves on a Coil Spring, Water Waves	-	4 (20%)	-	-
	Sound Waves	-	-	3 (15%)	-
	Reflection of Light, Refraction of Light, Thin and Thick Lenses, Colors, Electromagnetic Waves, Wave Nature of Light	-	-	-	7 (35%)
Matter and Its Properties					
	Mass, Volume, Density	1 (5%)	-	-	-
	Gases and Plasma	-	3 (15%)	-	-
	Pressure in Solids, Liquids and Gases	-	-	6 (30%)	-
Energy					
	Conversion of Energy	1 (5%)	-	-	-
The Nature of Physics					
	Scalar and Vector Quantity	1 (5%)	-	-	-
Modern Physics					
	Special Relativity	-	8 (40%)	-	-
	Particle Theory of Light, Matter Waves	-	-	9 (45%)	-
	Structure of Nucleus, Radioactivity	-	-	-	6 (30%)
Electricity and Electronic					
	Variable Current, Capacitors, Bobbins, Transformers and Elements of Electronic Circuit	-	-	-	9 (45%)

"According to you, why do students experience conceptual challenges in learning topics generally?" was the second question that was asked to the participating teachers. Teachers reported that the major reasons were the realization of mechanical learning without attributing meanings to the topic, lack of ability to do the mathematical operations, insufficient amount of hours allocated to teaching, existence of incomplete knowledge and misconceptions from past learning experiences, low level of student motivation and the development of negative attitudes towards physics due to the anxiety stemming from the upcoming university placement test, particularly observed in Grade 12 students (Table 4).

Table 4. The reasons for the conceptual challenges experienced in learning

	GRADE 9	GRADE 10	GRADE 11	GRADE 12
	Number of Teachers (%)	Number of Teachers (%)	Number of Teachers (%)	Number of Teachers (%)
Insufficient allocation of hours	15 (75%)	14 (70%)	15 (75%)	-
Lack of the ability to do mathematical operations	15 (75%)	8 (40%)	12 (60%)	8 (40%)
Realization of mechanical learning without attributing meanings to the topic	10 (50%)	11 (55%)	-	7 (35%)
Existence of incomplete knowledge and misconceptions from past learning experiences	8 (40%)	8 (40%)	1 (5%)	5 (25%)
Development of negative attitudes towards physics due to the anxiety stemming from the upcoming university placement test	11 (55%)	6 (30%)	9 (45%)	10 (50%)
Failure in provision of level-appropriate teaching for students	8 (40%)	5 (25%)	3(15%)	-
Inclusion of rather extensive knowledge in the curriculum	5(25%)	4 (20%)	9 (45%)	-
Teachers' lack of field knowledge	4 (20%)	3(15%)	3 (15%)	-
Failure to ensure student motivation	2 (10%)	1(5%)	14 (70%)	3 (15%)
Inclusion of abstract concepts in the topics	-	12 (60%)	5 (25%)	-
Lack of experimental applications within the topics	-	-	4 (20%)	-
Anxiety due to the upcoming university placement test	-	-	8 (40%)	18 (90%)

Table 4 shows that the major problem in Grades 9, 10 and 11 is found to be the insufficient time allocated to the teaching of the topics, which further leads to a quick pace of learning activities and hinders the performing of practical applications. Findings obtained from teachers interviews did not contain a reference by Grade 12 students to the problem of insufficient time allocated to the teaching (Table 4). This may be a result of the failure to execute level-appropriate teaching according to such statements of teachers as "Students have become distant to school. They do not want to come to school. When students are in Grade 12, they focus on the private supplementary courses and the university placement test. Even though students attend school, the lessons are quite unproductive or they practice test questions to prepare for the university placement test within the scope of its content."

The third question that was asked to the physics teachers was *“What are the teaching methods, techniques and strategies you use in teaching the topics that are challenging to learn conceptually for students?”*. Teachers mentioned that they preferred to use the instruction method, question and answer technique and problem solving method in teaching of the said topics (Table 5).

Table 5. Teaching methods, techniques and strategies used in teaching topics that are challenging to learn conceptually

	GRADE 9	GRADE 10	GRADE 11	GRADE 12
	Number of Teachers (%)	Number of Teachers (%)	Number of Teachers (%)	Number of Teachers (%)
Instruction method	20 (%100)	15 (%75)	20 (%100)	15 (%75)
Question and answer technique	9 (%45)	5 (%25)	1 (%55)	6 (%30)
Demonstration and Practice Method	7 (%35)	4 (%20)	6 (%30)	5(%25)
Demonstration Technique	6(%30)	4 (%20)	6 (%30)	6 (%30)
Problem Solving Technique	7 (%35)	8 (%40)	11(%55)	11(%55)
Individual Studying Technique	8 (%40)	5 (%25)	7 (%35)	-
Discussion Technique	5 (%25)	8 (%40)	-	3 (%15)
Analogy Technique	4 (%20)	3(%15)	6 (%30)	-

Interviews with the teachers revealed that the methods, techniques and strategies they used in teaching conceptually challenging topics were not any different from those they used in their usual teaching. The supporting opinions expressed by the teachers were as follows: (R: Researcher; T: Teacher; #: Number of Teacher):

R: *What are the teaching methods, techniques and strategies you use in teaching conceptually challenging topics?*

T2: *I usually prefer the instruction method. I sometimes make use of the question and answer technique and problem solving method.*

A: *Why do you prefer to use these methods, techniques and strategies?*

T2: *Because; I believe that I am able to provide students with more effective learning by using these methods, techniques and strategies, which I am used to implement for many years,*

R: *So, what are the teaching methods, techniques and strategies you use in general in teaching other than the teaching of the conceptually challenging topics?*

T2: *I use the same methods, techniques and in teaching of other topics.*

R: *Why is there no difference between the methods, techniques and strategies you use in teaching all topics?*

T2: *I have time limits with respect to the teaching of the topics and I don’t have much time for activities that require alternative methods, techniques and strategies.*

R: *According to you, do alternative methods, techniques and strategies have to be used in teaching of the conceptually challenging topics?*

T2: *Of course, that would ensure that students learn more meaningfully. However, in order us to use alternative methods, techniques and strategies, we should have more hours allocated to teaching.*

According to the interviews made, teachers believe that in order to use appropriate methods, techniques and strategies, the number of hours allocated to classes has to be increased.

“Considering the conceptual challenges, do you believe that you are able to address all the attainments indicated in the curriculum?” was the fourth question that was asked to the participating physics teachers. All teachers teaching Grades 9 and 11, 18 (90%) of the teachers teaching Grade 10 and 17 (85%) of the teachers teaching Grade 12 mentioned that they were not able to address all the attainments indicated in the curriculum due to the comprehensiveness of the topics and the insufficient allocation of time. Only, 2 (10%) of the teachers teaching

Grade 10 and three (15%) of the teachers teaching grade 12 mentioned that they were able to address all the attainments indicated in the curriculum. One of the teachers, who mentioned that s/he was able to address all the attainments indicated in the curriculum, expressed this as follows:

R: *Considering the conceptual challenges, do you believe that you are able to address all the attainments indicated in the curriculum?*

T15: *Yes, I am.*

R: *What do you think about the sufficiency of the time allocated to teaching the topics of the curriculum?*

T15: *The allocation of hours is not sufficient, topics are quite comprehensive; however, I teach very fast in or der to to address all the attainments indicated in the curriculum on time.*

R: *Does that have a negative effect on the students?*

T15: *Yes, it does. Students have difficulty in attributing meanings to the concepts when I teach fast.*

It was determined that the teachers, who were able to address all the attainments in the curriculum, taught very fast. However, as mentioned before, a fast teaching pace is believed to cause students to experience conceptual challenges in learning the topics.

"Are the topics that are conceptually challenging to learn related to the other disciplines? Please explain." was the fifth question that was asked to the physics teachers who participated in the study. Teachers mentioned that the topics that were challenging to learn in terms of concepts were related to mathematics, geometry and chemistry. Teachers reported that students' learning in mathematics, geometry and chemistry affected their performance in physics (Table 6).

Table 6. The relationship of the topics that are conceptually challenging to learn with other disciplines

	GRADE 9	GRADE 10	GRADE 11	GRADE 12
	Number of Teachers (%)	Number of Teachers (%)	Number of Teachers (%)	Number of Teachers (%)
Chemistry	8 (40%)	10 (50%)	10 (50%)	18 (90%)
Mathematics	14 (70%)	15 (75%)	14 (70%)	17 (85%)
Geometry	14 (70%)	15 (75%)	12 (60%)	16 (80%)

Opinions of teachers supporting the existence of a relationship between the topics that were conceptually challenging to learn and the other disciplines were as follows:

T9: *"Many topics such as radioactivity and nuclear structure coincide with the subjects of chemistry. We can treat these topics in a more comprehensible way with these students who learned and understood them in chemistry."*

T18: *"That the students are successful in mathematics and geometry positively affects the physics. The students can learn easily through the formulas and derivations."*

According to the opinions of the teachers, learning in chemistry, mathematics and geometry were effective in learning of physics meaningfully. As some topics of chemistry were related to the Grade 12 physics topics, it was identified that the teachers experienced less conceptual challenges than the other topics while teaching the relevant ones.

"What do you do to teach the topics that are challenging to learn conceptually?" was the sixth question that was asked to the participating physics teachers. It was found that the participating teachers preferred to exchange opinions with their colleagues and lecturers in the universities as well as benefiting from the international resources, and they believed that these choices had positive influences on teaching challenging topics. Another result of the research was that the teachers did not prefer to participate in in-service training activities (Table 7).

Table 7. The activities made by the teachers for teaching the topics that were challenging to learn conceptually

	GRADE 9 Number of Teachers (%)	GRADE 10 Number of Teachers (%)	GRADE 11 Number of Teachers (%)	GRADE 12 Number of Teachers (%)
Exchange opinions with colleagues	20 (%100)	20 (%100)	20 (%100)	16 (%80)
Exchange opinions with the lecturers in the universities	4 (%20)	5 (%25)	2 (%10)	6 (%30)
Benefit from international resources	-	2 (%10)	1 (%5)	5 (%25)
Benefit from their own experiences	1 (%5)	-	-	1 (%5)

"While teaching the topics in physics curriculum that will be gradually applied as of 2013-2014 school year, what elements may cause the students to have conceptual challenges while learning?" was the last question that was asked to the participating physics teachers. Teachers first explained their opinions about the New Physics Curriculum. A total of 30(79%) teachers thought that the new curriculum was better than the previous one while 31 (82%) teachers thought that it did not impose restrictions on teachers in teaching the topics in the curriculum and 35(92%) teachers believed that it did not comply with university placement test. Among the participants, 25(66%) teachers found the textbooks incoherent with the new curriculum and 34(89%) teachers thought conceptual challenges would reoccur in the new curriculum due to the ranking of the topics and insufficiency of the periods. Fifteen (75%) of the teachers who taught Grade 9 physics curriculum stated that Grade 9 New Physics Curriculum differentiated from Physics Curriculum in the second semester; however, while the ranking of the topics was better in the New Physics Curriculum (see Table 1, Table 1.1), the allocation of periods was insufficient and the titles in new textbook provided better motivation for the students. Five teachers (25%) mentioned that they appreciated the Physics Curriculum much more (See Table 2, Table 2.1). It was identified that 18 teachers teaching Grade 10 thought that was inappropriate to place the optics topic at the end of the semester, as it was a quite significant and comprehensive topic. Two teachers (10%) were found to believe that they would have troubles while teaching the topics, as they would have to step out of their routines due to the requirement of the New Physics Curriculum on not to introduce any numerical expressions. Besides, all the teachers of Grade 10 told that the periods allocated to teaching were insufficient and should be increased. In addition, all physics teachers of Grade 11 reported that a basic topic such as vectors which was placed in Grade 11 physics curriculum should have been taught at the beginning of Grade 9, it was not appropriate and it would be too late to teach it in Grade 11, and that this situation would cause some troubles as the students needed the knowledge of vectors while learning the topics listed prior to vectors. Among the participants, 19 teachers (95%) who taught Grade 12 stated that the topics were too intense considering the fact that the lessons were inefficient as students focused on the university placement test, they pushed the school in the background and focused on the preparatory courses due to their exam anxiety, or they stepped out of the curriculum and solved questions for university placement test. Teachers mentioned that the number of topics in the Grade 12 curriculum should be reduced. It was identified that they thought "Applications of Modern Physics in Technology" topic could be taught at the university level and it would be more appropriate not to apply a heavy curriculum to the high school students. One (5%) of the teachers told that he appreciated the Grade 12 curriculum as it was more comprehensive.

4. Conclusion and discussion

In the light of the data obtained in this study, which intended to identify the opinions of the physics teachers about the conceptual challenges experienced in teaching the topics of the physics curriculum; it has been identified that the students had difficulties in understanding concepts in motion, torque, simple harmonic motion topics in “Force and Motion”; in granularity of the light, wave feature of particles in “Modern Physics” unit; in alternate current, capacitors, bobbins, transformers and the elements of electric circuits in “Electric and Electronic” unit at most, and these challenges generally resulted from the insufficiency of the periods, the deficiencies of the students in numerical expressions and the fact that they learned mechanically without understanding the topic. According to the opinions of teachers, the curriculum has certain problems that stemmed from the ranking of the topics in New Physics Curriculum, the insufficiency of the periods, and these problems resulted in various conceptual challenges for students.

Referring to the opinions of participating physics teachers, it has been determined that the students have difficulties in understanding motion in “Force and Motion” unit in Grade 9, current in electric circuits, tension and electrical power in “Electric” unit and particularly in specific relativity in “Modern Physics” unit in Grade 10. It has also been determined that students found torque in “Force and Motion” unit challenging in Grade 11 as well as the granularity of the light and wave feature of particles in “Modern Physics” unit. In Grade 12, simple harmonic motion in “Force and Motion” unit, along with the alternate current, capacitors, bobbins, transformers and the elements of electronic circuits in “Electric and Electronic” unit were challenging for the students to learn. The reasons why students had difficulties in learning the topics in physics curriculum were identified as follows: mechanical learning without understanding the topic, the deficiencies of the students in numerical expressions, the insufficiency of the periods allocated, the knowledge deficiencies and misconceptions of the past learning experiences, lack of motivation, inappropriate level of teaching for the students, inclusion of abstract concepts in the “Modern Physics” unit (Wosilait, Heron, Schaffer, & McDermott, 1999), deficiencies of teachers in the field of expertise, the intention of teachers to give more information than required in the curriculum, the inability to perform experiments in teaching of the topics, and the negative attitudes of students towards physics due to the anxiety of the university placement test, particularly experienced in Grade. Previous studies have shown that misconceptions occurred when the students studying for the university placement test were not able to learn the topics thoroughly, the topics were explained superficially and fast due to the insufficiency of the periods, the students were incompetent at numerical expressions due to their prejudices about mathematics and these deficiencies affected the teaching of physics (Çınar & Teyfur, 2006; Yaygın & Dindar, 2007; Karakuyu, 2008; Tüysüz & Aydın, 2009; Kutluca & Aydın, 2010). It has been identified that the reason why all the acquisitions in the curriculum could not be addressed was the intensity of the topics and the insufficiency of the periods according to the opinions of most teachers. The study by Göçen and Kabaran (2013) is also supportive of the findings of this research. They have stated that in cases where the periods cannot be increased, decreasing the number of the acquisitions in the curriculum can reduce the load of each lesson, and they think the teacher can teach and observe the students more easily in a longer period. In the light of these studies, it is believed that decreasing the number of the acquisitions or increasing the length of the periods could be implemented to overcome the insufficiency of the period, which is a frequent problem.

It has been found that the physics teachers used instruction method, inquiry method, modeling method, demonstrating method, problem solving method, individual studying method, discussing method and analogy method while teaching the topics that were challenging to learn conceptually. In the research, it was found that the usual methods, techniques and strategies of the teachers were not different from the methods, techniques and strategies that they used while teaching challenging topics (Karakuyu, 2008; Kapucu, 2010). It is believed that instead of using the same method, technique and strategies while teaching the topics that are challenging to learn conceptually, teachers should benefit from different methods, techniques and strategies, which are open to changing and development and as well as being appropriate for the level of the students, ensuring the achievement of curriculum goals, embodying the topic and addressing more than one sense organs in accordance with the topic.

Teachers are determined to think the topics that are challenging to learn conceptually are related with mathematics, geometry and chemistry. Besides, it has been emphasized that some topics of chemistry are related with especially topics of Grade 12. The relationship between these three disciplines and physics is that according to teachers, the students who have no deficiencies in math, chemistry and geometry or have learned these lessons meaningfully have less conceptual difficulties in the topics that are related with these three lessons compared to other topics. When physics and chemistry curriculum are analyzed, it is seen that some topics of chemistry are related to radioactivity and nuclear structure in "Modern Physics" unit in Grade 12 physics curriculum at most. There are some teachers who think that this relationship has some positive effects. In addition, considering the high number of acquisitions in physics curriculum and inadequate periods, and the suggestion of Özdemir et al. (2011) to reduce the number of the topics in physics curriculum, it is would be appropriate to revise the topics that are common in physics and chemistry and design the curriculum in such way that these topics will not be repeated.

In-service training activities contribute to the continuity of the education of teachers and continuous updating of teachers' knowledge (Kanlı, 2001). It has been identified in this research that the teachers prefer to exchange opinions about the topics that are challenging to learn conceptually with their colleagues and the lecturers in the universities, and benefit from the international resources and their own experiences; however, they do not prefer to participate in in-service training activities as they do not mention anything about benefitting from these activities. The reasons why they do not prefer to benefit from these in-service training activities may be that they think these activities are not effective in developing their professional knowledge and skills as Kanlı (2011) has stated in his research. These training activities are believed to be more preferable if they are reorganized in such way to improve teachers' professional knowledge and skills, alternative solutions are found for the passive listener role of the teachers, teachers are encouraged to participate in these activities and the activities are performed by the experts.

Among the principles agreed upon without grounding on only one model, approach or method in New Physics Curriculum, it has been adopted that the students learn by interpreting the new knowledge using their previous knowledge (MONE, 2013). But after the interviews with teachers in this research, it has been found that there were certain problems resulting from the ranking of the topics in the New Physics Curriculum. In accordance with the result, it can be said that the absence of the relationship between the rankings of the topics in the curriculum does not coincide with the adopted principle and this problem may complicate the conceptual learning. Other conclusions of this study are as follows: the ranking of the topics in Grade 9 physics curriculum and the change of titles in the textbook have a positive influence on the students (see Table 1); the place of optics topic that is the last topic in Grade 10 physics curriculum should be changed as it is an important and comprehensive topic; vectors as a basic topic of Grade 11 physics curriculum should be among the first topics of Grade 9; the intensity of the topics should be reduced as the requirements of Grade 12 curriculum cannot be met due to the fact that the students focus on the university placement test and push the school in the background and attend preparatory courses. In addition to these results, it has been identified that it would be more appropriate to teach the "Application of Modern Physics in Technology" at the university level instead of Grade 12. Other opinions of the teachers teaching Grades 9, 10, 11 and 12 about New Physics Curriculum are as follows: it does not impose any restrictions on the teachers about teaching the topics of the curriculum contrary to the previous one; the content of the curriculum is more simple; the number of teaching hours allocated is insufficient and should be increased; the textbooks are not coherent with the new curriculum, and the curriculum is not coherent with the university placement test. In order to eliminate this problem, either the university placement test should be modified to comply with this curriculum, or a curriculum that is more compliant with the university placement test should be developed (Kutluca & Aydın, 2010; Nartgün et al., 2011). In the research conducted by Yiğit (2013), it was stated that teachers did not want to adhere to a theory directly within the teaching-learning approach in the New Physics Curriculum. Due to the independence emerging from the fact that teachers can teach without adhering to a theory directly within the teaching-learning process, it is believed that there will be differences in the ways teachers teach, which would lead to conceptual challenges and negative influences for teachers.

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