JOURNAL OF BALTIC SCIENCE EDUCATION
ISSN 1648-3898

HELPING PRE-SERVICE SCIENCE TEACHERS TO UNDERSTAND ATOMISM THROUGH OBSERVATIONS AND EXPERIMENTS

Ayse Oguz Unver,
Sertac Arabacioglu

Abstract. *Current atom concept teachings haven't reached required levels from the points of both teaching methods and learning attainments. With this purpose in this research atom concept is conveyed to the classroom milieu through observations and experiments related to the atom concept during historical development process starting with the masterpiece of, the carrier of the atom thoughts of Antiquity to our age, Roman philosopher Lucretius, namely De Rerum Natura. The study has conducted thoughts regarding the atom in ancient and subsequent history under six headings teaching modules that would span over 11 weeks. The participants in the study were 73 pre-service science teachers. The two-tier multiple-choice diagnostic test was developed. In the analysis of the results of the test, after test hypotheses were proved, the single-factor ANOVA was employed for related samples, while frequency analysis was used for the content of the views of the participants and percentages were calculated to observe the change in alternative conceptions.*

Key words: *concept of the atom in antiquity, experiments and observations, Titus Lucretius Carus, Two-tier Multiple-Choice Diagnostic test.*

Ayse Oguz Unver,
Sertac Arabacioglu
Mugla Sitki Kocman University, Turkey

Introduction

The emergence of the atom as a concept is as old as the history of science and philosophy and the atom itself represents a mighty and dynamic integration of knowledge. The first questioning of the origin of the universe in the first half of the 6^{th} century B.C. is probably due to Thales of Miletus. Aristoteles called *physicists* Thales and the philosophers who dealt with the physical problem of the origin and material composition of the universe and lived before Plato. In this period several schools of thought were born. The most important centers became cities as Miletus (Aydın, Balat), Elea (South-western Italy, Velia in the region of Campania) and Abdera (Avdira, Greece). This is the context in which atomism was born, too. Such doctrine became one of the most important teachings of the ancient world (Capelle, 2006). The process is as yet unfinished and atomic thought continues to be the subject of multinational, gigantic projects that resume the searching of the philosophers of antiquity and every day, there is new knowledge gained.

The Progenitors of the Atom Concept of Antiquity

In generic meaning, the first root of atomic thought was believed started of the 6th century B.C. by physicist Thales. The pioneering efforts of Thales in search of *arche* gave fruit one century later when Leucippus furthered the concept by suggesting an indivisible *arche* (*arche atomos*). Subsequently, Democritus and Epicurus contributed to the development of the concept of the atom and the subject became the basis for teaching the elements in the philosophy schools of the time. These teachings were transferred to younger generations through the work of philosophers such as Titus Lucretius Carus, Marcus Tullius Cicero and Lucius Annaeus Seneca. It can be seen that only certain fragments of the atomic views before Lucretius have reached us today. The first mature work to clearly carry the atomism of antiquity into contemporary times was written in the 1^{st} century B.C. by Lucretius, under the title *De Rerum Natura* (Sarigollu, 1973). Especially in the modern era in which we live and in the light of the level of scientific knowledge that exists today, it would be erroneous to seek scientific validity in the pioneering thoughts of the ancients. The work mentioned, however, offers us important information about the patterns of thought that gave birth to the concept of atomism in antiquity and the approaches to the subject in those times (Eyupoglu, 2001). The work is of importance in that it sets forth how the early philosophers leaned toward nature in attempting to prove the existence of the atom, how they interpreted the various phenomena of nature, and how they presented whatever knowledge they gained. Therefore, the contribution of these authors to the learning process should not be overlooked. These pioneering thoughts lead students on their way to learning the concept of the atom, observing and reaching the notion of the atom just like the philosophers did in antiquity.

In present-day education, there is an erroneous approach that originates from much earlier days. For a long time, Aristotle's (384-322 B.C.) anti-atomic stance had an impact on atomic thought that clearly lasted for more than 2000 years (Bogaard, 2012; Nussbaum, 2005; Thagard and Toombs, 2005). The reason for this was possibly Aristotle's prestigious reputation in the area of science but also his mentorship of the Macedonian king, Alexander the Great. It was Alexander the Great who carried the philosopher's works to the eastern parts of the world, all the way to the lands of the Persians and even to India, after his conquests. Even in this period, however, atomism was always an accepted teaching among certain groups. Over the course of history, many philosophers and scientists such as Francis Bacon, Pierre Gassendi, Robert Boyle, Antoine Lavoisier and John Dalton set forth views that defended atomism (Thagard and Toombs, 2005). They were unable to gather much momentum, however, in the face of Aristotle's views. In the 1800's, experimental and theoretical atomism, nurtured by the atomism of antiquity, reached its peak, breeding such important thinkers as J. Dalton, J. J. Thomson, E. Rutherford, and N. Bohr. Atomistic thinking in today's modern world is neither a synthesis of these thoughts, nor has it been negated. For this reason, the teaching of the concept of the atom requires a historical perspective that encompasses all aspects of atomistic thought. It can only be through teaching the atom in this way that instruction will be effective and meaningful. From a historical point of view, teaching the concept of the atom needs an integrated approach that takes into account all epistemological aspects. All exercises related to the development of the concept of the atom over the span of history and all sub-concepts should be included in the instruction. In doing this, a chronological order should be kept so that content is organized consecutively. Examples of historical content organization can be found in the literature. It has been found that a historical perspective renders positive results in teaching concepts such as the atom and various applications have shown that this is an effective approach (e.g., Ben-Zvi, Eylon and Silberstein, 1986). Figure 1 was drawn up by the researchers in the light of this information and constitutes a summary of the notion of the atom in antiquity.

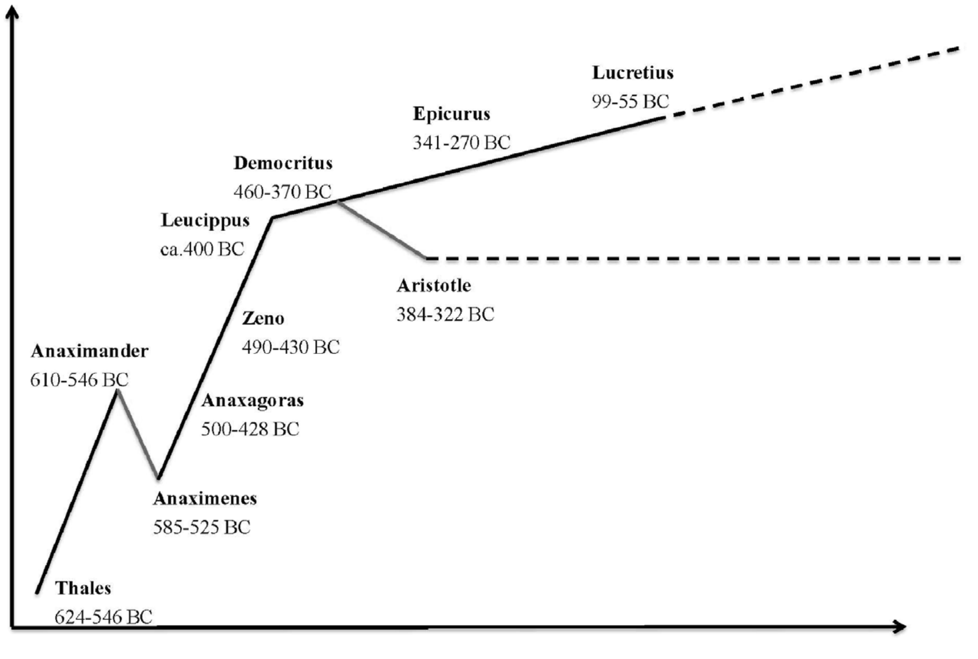

Figure 1: Birth and development of the notion of the atom in antiquity.

A Review of Research and Implications for Educating Students about the Atom

How accumulated knowledge about the atom is to be transferred to younger generations and with which methods is an important issue. Approximately 2600 years before today, the nature of matter and the questioning of basic elements were subjects of inquiry at the school of Miletus; two centuries later, atomistic views were formulated in the Eleatic school of thinking. The most concrete evidence of how the philosophers gathered their atomistic thoughts from nature and transferred the data they gained can be seen in the work entitled *De Rerum Natura*, written by the Roman poet and philosopher Titus Lucretius Carus (*ca.* 95-55 B.C.). In today's world, however, a consensus has not been reached as to the methods and examples that need to be used in teaching the atom in contemporary education. Our teaching of the atom sets itself apart not only from the atomistic thinking of antiquity, but also from modern atomistic thought as well (Taber, 2003). This is reflected in studies in the literature of the field. Some studies in the literature make assessments of methods and strategies of teaching in answer to the question, "How should the atom be taught?" (e.g. Cokelez and Dumon 2005; Harrison and Treagust, 2000; Niaz, Aguilera, Maza and Liendo, 2002), while others set forth evaluations of content and student views with regard to the concept of the atom in an attempt to answer the question, "What should be taught with respect to the concept of the atom?" (e.g. Albanese and Vicentini, 1997; De Posada, 1997; Gilbert and Watts, 1983; Griffiths and Preston, 1992; Harrison and Treagust, 1996; Novick and Nussbaum, 1978; Park and Light, 2009; Taber, 2003).

Existing forms of instruction on the atom that have been analyzed, as mentioned above in terms of content should also be assessed in terms of teaching methods and strategies. Over the course of the education process, fundamental knowledge on the concept of the atom is first treated in elementary school within the context of the concept of matter. Direct reference to the word "atom" and to the concept of the atom is made in middle school. Forms of modeling are frequently employed in teaching the concept, among these "Dalton's Atomic Model," using a solid sphere, the "Thomson Atomic Model," which represents the atom as a solid sphere that resembles plum pudding model, the "Rutherford Model," with its electrons orbiting in a circle like planets around a central nucleus, and the "Bohr Model," a model similar to the solar system, where more than one planet can be in the same orbit. However, models do not totally reflect the scientific knowledge they were made to represent. In particular, their epistemological aspects are open to discussion (Gilbert, 2004). According to Cokelez and Dumon (2005), models are born from resources produced by society parallel to scientific developments. It is for this reason that using models to transfer knowledge to students when educating them about the atom is an inadequate technique. When educating students about the atom, knowledge should be presented directly and from primary sources. Students will form diagrams of their own models in their minds later. Because of this instruction on the basis of modeling has always been the subject of questioning (e.g., Gilbert, 2004; Harrison and Treagust, 1996; Stefani and Tsaparlis, 2009). On the other hand, the difficulties in learning and the misconceptions involved in teaching on the basis of modeling have frequently been reported (e.g., Albanese and Vicentini, 1997; Cokelez and Yalçın, 2012; Griffths and Preston, 1992; Harrison and Treagust, 1996, 2000; Justi and Gilbert, 2000; Niaz, Aguilera, Moza and Liendo, 2002; Osborne and Cosgrove, 1983; Park and Light, 2009; Schmidt, Baumgartner and Eybe, 2003; Taber, 2005). As Sewell (2002) has said, there is a need for suitable teaching methods that overcome learning difficulties and avoid misconceptions in instruction about the atom or the concept of the atom.

In the present study, therefore, using as a starting point the atomic views of Lucretius, who managed to carry atomism from antiquity into today's world, the researcher intended to examine the historical progress that gave rise to the changes and phases of development of the concept of the atom up until contemporary times and, in doing so, to evaluate the development of consecutive activities based on observation and experimentation and the measurement tools that have been developed and applied to teaching pre-service science teachers.

Methodology of Research

Research Model

The research was planned as a pre-experimental, one-group pre-test/post-test design model. To determine the sample's retention of the study experiment, an additional retention test was carried out 3 months after the post-test.

Participants in the Research

The participants in the research were 73 (51 female and 22 male students) pre-service teachers enrolled in the third undergraduate year of the Science Teaching Department of the Faculty of Education of a university in western Turkey. The applications of the research were conducted within the scope of the course "Science and Technology Laboratory Applications I" given in the 3rd year of the Undergraduate Science Teaching Program.

Data Collection Tools

The two-tier multiple-choice diagnostic test was used as a data collection instrument (Chandrasegarana, Treagust and Mocerino 2007; Law and Treagust, 2007; Treagust, 1988). The researchers developed the test in three stages, as shown in Figure 2.

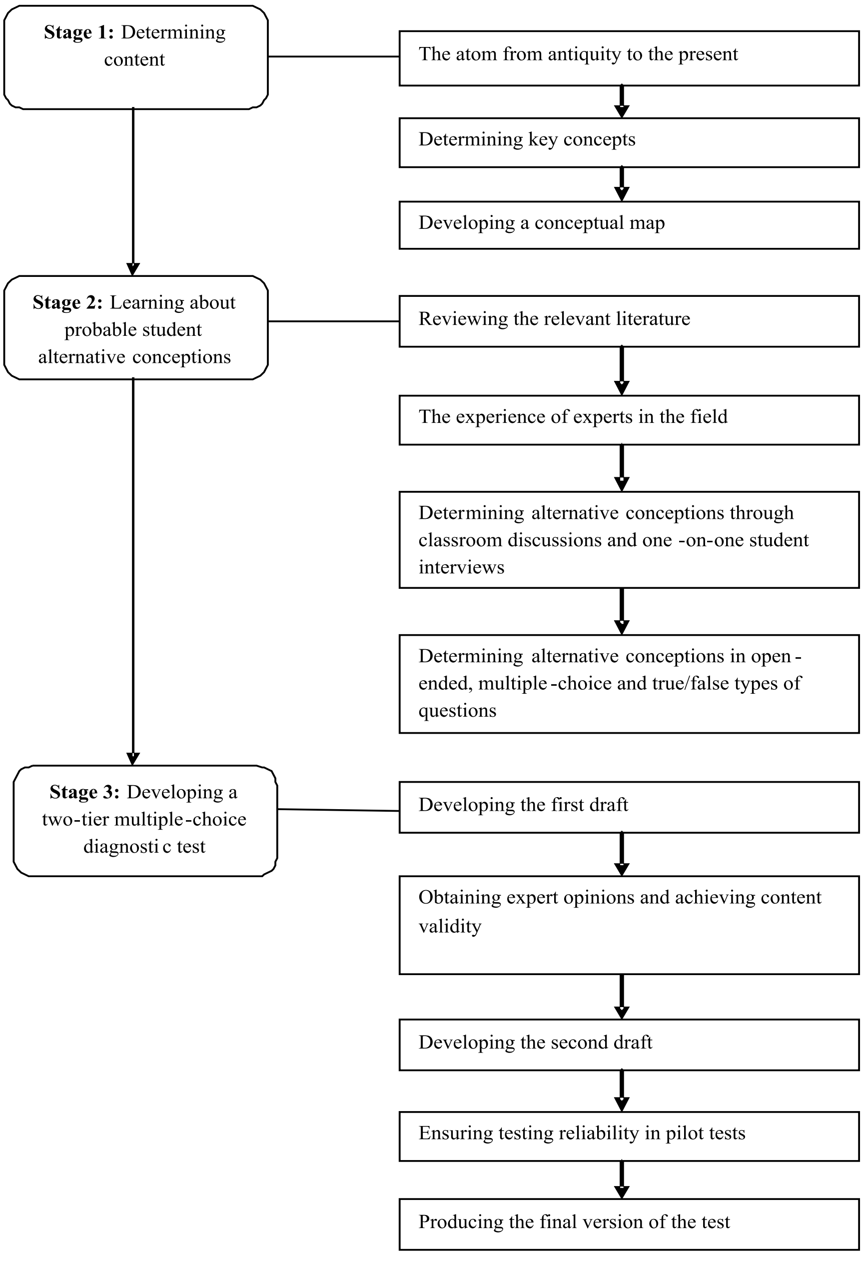

Figure 2: Stages followed in the development of the test.

ISSN 1648–3898

In the first stage of the test, a statement was presented to the students and they were asked to respond as "right/wrong/I don't know". The second stage involved sentences that could be grounds for the answers given in stage one. In order to evaluate the different reasons the students may give for their answers, they were provided with a space marked "Other" with room in it to supply an open-ended response. Four faculty members - one a specialist in quantum physics, one a physics teacher and two science experts--were enlisted to provide their opinions in order to validate the scope and appearance of the questions that had been set up. Revisions were made according to the opinions of the experts. The pilot implementation of the test was then conducted and, following the reliability analysis, a 23-question test was formulated as seen in the Attachment.

The alpha coefficient (α) calculated on the basis of the combined values of the two stages of each question, where right answer-right reason=3 points, wrong answer-right reason=2 points, right answer-mistaken reason=1 point, wrong answer-mistaken reason or leaving blank=0 points. The α value calculated for the test was 0.68 on the pre-test, 0.62 on the post-test and 0.65 on the retention test. Nunally and Bernstein (1994) point to a medium reliability of 0.5-0.7, that can be accepted for cognitive tests. A lower limit of 0.50 is suggested for the α value on achievement tests administered in the classroom environment (Kehoe, 1995).

Content of Teaching Modules

The developments that constitute the turning points of teaching the concept of the atom from the time of Lucretius up to the present were considered within the framework of *activities based on observation and experimentation* and set down under 6 headings in teaching modules that would span over 11 weeks.

In formulating the scope and content of the modules, inspiration was derived from: (1) the knowledge provided in the curriculum about the concept of the atom; (2) the observations set forth in the work, "De Rerum Natura," written by Lucretius; (3) research in the literature on the concept of the atom; (4) the works of researchers such as Bohr, Dalton and Rutherford, as well as the websites of various research organizations (e.g., CERN, TÜBİTAK, etc.); and lastly, (5) the views of researchers working in the field of quantum physics and experiments conducted in the quantum physics class laboratory. All of this data contributed to the development of the modules; their content was reviewed by the three experts in the field. A week before the modules were to be implemented, the pre-service teachers were encouraged to review articles in the popular science magazines and various related websites to arouse their curiosity and so that these would provide guidance when they began to learn about the observations and experiments in the module. The modules used in the research, and their content is as follows:

Module 1: The Birth of the Notion of the Atom in Antiquity

This teaching module presents pre-service teachers with the notion of the atom in antiquity against a perspective of time, place and events. The module is composed of four sub-headings.

Miletus: The Place where Knowledge Turned into Science: A week before the activities began, an epigrapher from the Archeology Department of the University where the research was being conducted presented a conference on the period of history spanning from Thales (c. 600 B.C.) to Lucretius (c. 70 B.C.), focusing on the birth of science in the region of Anatolia and the pioneering schools of thought that led to the accumulation of scientific knowledge and the notion of the atom.

Figure 3: A view of the trip to the ancient city of Miletus.

A day in Miletus: In the second week of the module, a trip was organized to the ancient city of Miletus. The principal goal of the trip was to raise awareness among the pre-service teachers about the region of West Anatolia and the contribution it made to science, and to offer information about the conditions of the time and the place at which the concept of the atom first appeared on these soils in those years of antiquity (Figure 3).

The Macro-Micro View of the World: At this point, various different observation activities are conducted to demonstrate the size of the atom and difference between the macro- and micro worlds. For example, an observation activity is conducted where the different cross-sections of an orange are shown to explain how the different parts of a whole are perceived in various observable dimensions and students are asked to become acquainted with these (Figure 4).

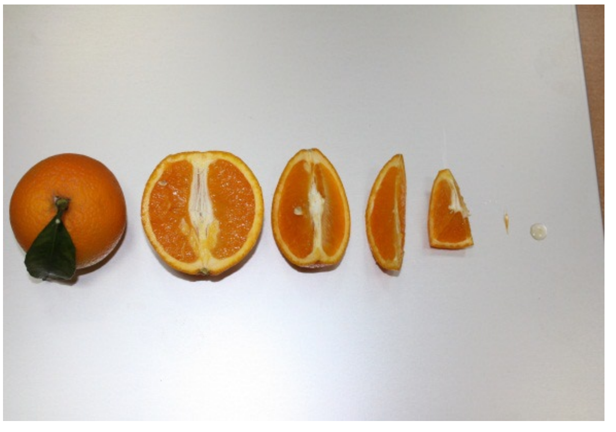

Figure 4: The orange activity to demonstrate the macro/macro-world.

Observations about the notion of the atom in antiquity: In this part of the activity, the concept of the void brought forth from the atomistic views of the philosophers of antiquity and the concepts of *arche* (the origin) and infinity are explained with a demonstration based on scientific thinking (Author(s), 2014; Nussbaum, 2005). The "syringe activity" is conducted to discuss the concept of the void. In this activity, students are given a syringe and an eraser and asked to press the eraser down on the syringe (Figure 5). A discussion is launched based on the observation of the nature of the spaces and the void between the particles making up the air (atoms/molecules) and at this point, the teachings and paradoxes of the ancient philosopher Zenon about the void are mentioned.

Figure 5: Images from the observation activity on the concept of the void.

An activity using soap is then carried out to lead the students into perceiving infinity or finiteness by making use of the truth claimed by Leucippuos and Democritus that the atom was solid and indivisible (Figure 6). The activity is based on an argument in the work of Lucretius, "*De Rerum Natura*," which was used by Baine (2007) to explain the birth of the concept of the atom.

ISSN 1648–3898

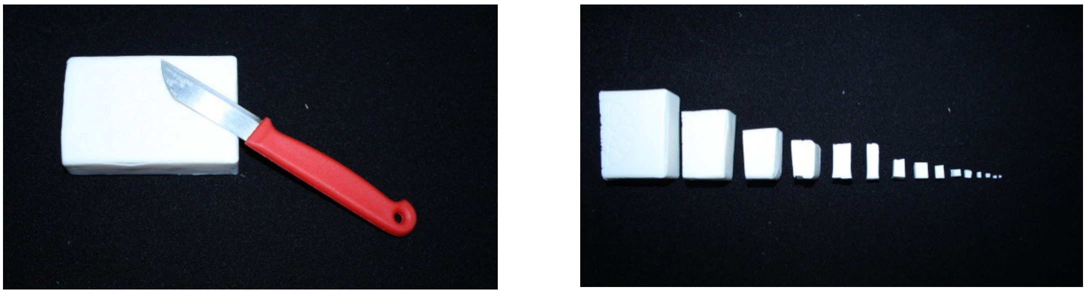

Figure 6: Images from the observation activity on the concept of the infinity.

Module 2: The Rebirth of the Notion of Atomos; J. Dalton and the Theory of the Atom

This module aims to give pre-service teachers an idea about the development of the notion of the atom in chemistry (particularly in the 18th and 19th centuries), the work of J. Dalton and the contributions of other pioneers in this context. The module was conducted in two steps: "Initial Experiments I: The Flame Test" (Figure 7) and "Initial Experiments II: The Conservation of Mass" (Figure 8).

Figure 7: Image from the observation activity on the flame test.

Figure 8: Image from the experiment conducted on the Law of the Conservation of Mass.

Module 3: Work that Led to the Discovery of the Electron and Thomson's Atomic Theory

The aim of this module is to stimulate the pre-service teachers to question the process that led to the discovery of the particle of the atom called the electron, basing their inquiry on phenomena they observe in their own environment (magnets, static electricity, etc.). The module comprises three stages: "Initial Experiments III: Electrostatic Experiments," "Initial Experiments IV: Observations of Cathode Rays and the Discovery of the Electron," "Initial Experiments V: Writing with Ions" (Chandra, 2008) (Figure 9).

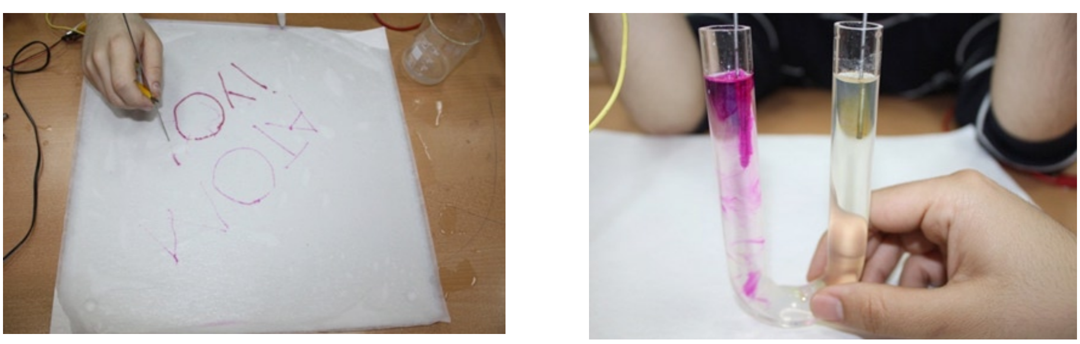

Figure 9: Images from the activity on writing with ions.

Module 4: The Discovery of the Nucleus; Rutherford's Atomic Theory

This module aims at clarifying how the nucleus of an atom was discovered based on the knowledge of X-rays and radioactive radiation. Another goal of the module is to provide an introductory activity as a means of observing the existence of the atom through an experiment on Brownian motion. This module is made up of three stages: "Initial Experiments VI: "Brownian motion," "Initial Experiments VII: The Nature of Light" and "Initial Experiments VIII: Rutherford Experiments."

Module 5: Bohr's Atomic Theory

Bohr's atomic theory was set forth in the footsteps of the pioneering work of Max Planck and of Albert Einstein's studies on the structure of light and the photoelectric effect. The fundamental inquiry in Bohr's atomic theory is based on the motion of the electron inside the atom. The goal here, therefore, was to start from the wave-particle duality of light and to use an experiment on the photoelectric effect to raise awareness about the points that the Rutherford atomic model could not explain or falsified, to teach the concept of levels of energy and the motions of electrons between levels of energy, and to explain Bohr's energy levels. The module comprises "Initial Experiments IX: Using a Crookes radiometer to observe the Duality of Light," "Initial Experiments X: Falsifying Rutherford's Atomic Theory and Bohr's Atomic Theory," and "Photoelectric phenomena" (Figure 10).

Figure 10: Images from the experiment on the photoelectric effect.

Module 6: Latest Developments regarding the Concept of the Atom; Modern Atomic Theory; Sub-atomic Particles and CERN

This module aims to teach pre-service teachers the prominent theories that led to modern atomic theory, and about sub-atomic particles and the concept of antimatter. In addition, this module included a trip that was organized to the university research center. The aim of the trip was to have students become aware of how scanning tunneling microscopes work. Moreover, students have to observe the results gleaned from microscopes that have demonstrated the existence of atoms. For this purpose, the teaching module contains three headings: "Modern Atomic Theory," "Sub-atomic particles and antimatter," and "Scanning tunneling microscopes".

Results of Research

In order to evaluate the effect of the activities developed in the study on the views of the pre-service teachers about the concept of the atom and to determine how much knowledge they had retained, a one-way repeated measures ANOVA test was performed to discover if there were significant differences between the students' pre-test, post-test and retention test total scores. The total scores from the data obtained from the pre-test, post-test and retention test and the findings regarding their central tendencies and distribution are presented in Table 1.

ISSN 1648–3898

Table 1. The pre-service teachers' pre-test, post-test and retention test total scores and their central tendencies and distribution.

	N	Mean	SD
Pre-test	73	30.699	7.642
Post-test	73	43.452	6.916
Retention Test	73	43.055	8.359

The hypothesis of sphericity is significant in situations where the number of repeated measures is three or more (Field, 2005). In the analysis, the Mauchlysphericity test validated the hypothesis (χ^2 (2) =2.06, $p > .05$); therefore, the variances in the universe of the score differences calculated for any two levels of the intragroup factor are equal. There was a significant difference between at least one of the pre-test, post-test and retention test scores of the pre-service teachers participating in the research [$F_{(2, 144)} = 118.902$, $p < .05$].

In order to determine the source of the significant difference between the groups and avoid Type I errors, the Bonferronni test "Holms' Sequential Bonferronni Procedure" was followed to perform a t-test (Pallant, 2007). Paired Samples t-Test results showed a significant difference between the pre-test and post-test scores: t (72) =-14.735, $p < .05$. There was also a significant difference between the pre-test and the retention test scores: t (72) =-12.309, $p< .05$. There was no significant difference between the post-test and the retention test scores: t (72) =.420, $p > .05$. In the light of these findings, it can be said that the observation and experiment-based activities in the modules had a positive effect on the views of the pre-service teachers about the concept of the atom. Furthermore, the absence of a significant difference between the mean scores of the post-test and the retention test indicate that there was no difference in the measurement results and that the effect of the implementation continued. In addition, the effect size of teaching materials that were developed on the learning of the concept of the atom was calculated as η^2= .750. According to Cohen, Manion and Morrison (2007), the eta-squared effect value is defined as 0.01 =very small, 0.06=medium effect and 0.14=very large effect. It may be said from the results that the study had a large effect.

When a more in-depth analysis was made of the responses of the prospective teachers to the questions on the pre-test, post-test and retention test, the findings about the conceptualizations of the students were found to be interesting yet consistent. The results showed consistency with the studies in the field literature but they also shed light on some alternative concepts that are not mentioned in the literature. The method used by Peterson, Treagust and Garnett (1986) was employed to determine that the pre-service teachers had alternative concepts. In line with this method, the pre-service teachers were said to have alternative concepts when they answered the first part of the question incorrectly and supported this wrong answer with a misconceived reason. At the end of the analysis, a particular alternative notion is accepted to be significant and widespread, if it is observed in at least 10% of the study group (Chu, Treagust and Chandrasegaran, 2009). Accordingly, the alternative concepts and the changes in the views of the prospective teachers on the pre-test, post-test and retention test about the atom are presented in detail in Table 2. In addition, the alternative concepts in the table were compared with the literature and the new alternative concepts about the atom set forth by the participants in the study were reported in the table.

Table 2. General alternative conceptions determined from the administration of the atom diagnostic instrument.

		% of students			
Item	Alternative conceptions	Before procedure	After procedure	Retention (3 months later)	Reference & Alternative conceptions
Q22	Atoms are the most fundamental form of a substance; the cell is the most fundamental form of a living being.	79.5	37	49.3	Kaya, 2010 "The atom is the most fundamental and simplest structure in a cell"

		% of students			
Item	Alternative conceptions	Before procedure	After procedure	Retention (3 months later)	Reference & Alternative conceptions
Q19	Atoms have bonds that tie them to each other.	50.7	35.6	35.6	
Q18	All of the atoms in a molecule are the same.	43.8	23.3	37.0	Kind, 2004 "Atoms have the properties of bulk matter"
Q2	Ethyl alcohol molecules expand under the effect of room temperature; they grow and become lighter, moving away from the environment.	30.1	20.5	20.5	Berkheimer, Anderson, Lee, & Blakeslee, 1988 "'When ice melts into water, it loses weight because ice is solid or hard"
Q17	Electrical currents in solutions are caused by atoms changing places.	26	9.6	14.7	
Q17	Negatively charged electrons flow into the spaces where there are more positively charged atom nuclei.	26	16.4	17.8	
Q2	Ethyl alcohol separates into hydrogen, oxygen and carbon atoms and turns into gas.	24.7	14.7	16.4	
Q20	Electrons revolve around themselves in spaces that suit their own level of energy.	24.7	6.8	15.1	Harrison &Treagust, 1996 "Each electron spins around the nucleus"
Q13	Because there are no spaces in between the particles of solids, they cannot move.	23.3	6.8	2.7	Berkheimer, Anderson, Lee, & Blakeslee, 1988 "Water molecules move freely with much more space between them than in the liquid or solid state."
Q6	Atoms are just like marbles; they are spheres that are solid inside.	23.3	12.3	6.8	Griffths& Preston, 1992; Harrison&Treagust, 1996 "An atom resembles a solid sphere, atoms are most like a hard polystyrene sphere."
Q21	O2 and H2 dissolved in water move away from the environment.	23.3	11	16.2	Osborne & Cosgrove, 1983; Berkheimer, Anderson, Lee, & Blakeslee, 1988 "Condensation occurs when hydrogen and oxygen in the air combine to form water."
Q20	Electrons exist in orbits that are like the rings in the solar system.	21.9	4.1	5.5	Cross, Mauvan, Chastrette, Leher, and Fayol, 1986 "Atoms have electrons circling them like planets around a star."
Q10	Because one of the basic building blocks of the atom is the electron, when electrons are pulled away, this leads to the division of the atom.	20.5	9.6	8.2	
Q21	When water boils, the water molecules turn into air molecules.	19.2	5.5	4.1	Berkheimer, Anderson, Lee, & Blakeslee, 1988 "The bubbles in the boiling water are air."
Q16	Matter can be divided into sub-atomic particles.	16.4	12.3	9.6	
Q7	Air is flexible so therefore atoms are flexible too.	15.1	13.7	12.5	deVos&Verdonk, 1987 "Soft matter cannot be made of hard molecules."
Q21	When water boils, the water separates into its components.	13.7	5.1	5.1	Osborne & Cosgrove, 1983 "The bonds in water molecules were broken when water changed state."
Q8	In the change of state, the atoms of hydrogen and oxygen that make up water divide up and form small molecules.	13.7	4.1	8.2	Osborne & Cosgrove, 1983; Berkheimer, Anderson, Lee, & Blakeslee, 1988 "Condensation occurs when hydrogen and oxygen in the air combine to form water."

ISSN 1648–3898

		% of students			
Item	Alternative conceptions	Before procedure	After procedure	Retention (3 months later)	Reference & Alternative conceptions
Q17	Electrons are particles that conduct electricity.	12.3	8.2	1.4	
Q8	In the change of state, a part of the hydrogen evaporates and moves away and the water molecules get smaller.	12.3	9.6	6.4	
Q1	Some of the carbon atoms break up into small pieces and fall off and so these atoms get smaller.	11.0	1.4	2.7	
Q15	The mass of an atom depends on how many atoms it's made up of.	11	5.5	9.6	
Q5	Atoms are alive because they move.	11.0	1.4	4.1	Griffiths &Preston, 1992 "Atoms are alive because they move."

(The figures in bold indicate alternative conceptions held by more than 10% of the students)

The pre-service teachers' more significant alternative concepts that are accepted to be more widespread (offered by at least 10% or more of the participants) are shown in Table 2. The alternative concepts have been expressed according to the percentage before the instruction, in order, from greatest to smallest. In addition, the table also includes the changes after the instruction and three months later. A review of the findings in the table indicates the striking observation that the pre-service teachers' conceptualizations went through some definite changes following the instruction. An examination of the table shows that many of the alternative concepts found in this study are similar to what has been revealed in previous studies but that some alternative concepts are unique to this study and many of them have been eliminated.

Discussion

The developments regarding the concept of the atom from the time of Lucretius up to the present day were evaluated with an academic tracking test that assessed the teaching modules and their effects using consecutive observations and experiments. It was observed that the instruction carried out was positively effective and permanent in terms of teaching the subject of the atom. Students recognized that the atom thoughts have its roots from Antiquity of our age. Correspondingly, some studies have also reported that the concept of the atom is the product of a school of thought that was developed before Democritus, for example, that Pythagoras (e.g. Bunge, 2003), Anaxagoras (e.g., Bogaard, 2012), Zenon (e.g., Pauri, 2003) Leucippus (e.g., Justi and Gilbert, 2000; Nussbaum, 2005; Thagard and Toombs, 2005) and Democritus (e.g., Harrison and Treagust, 1996; Matthews, 2011; Park and Light, 2009) played the most significant roles in the development of the concept of the atom.

Only certain fragments of information about the concept of the atom have survived over the centuries, from Thales to Leucippus, from Democritus to the present. Because of this, Lucretius and all of his works that have survived to the present day are important in terms of how they represent the clearest and most mature form of the thinking processes of antiquity. Thagard and Toombs (2005) have provided a similar view, pointing to the work of Lucretius, *De Rerum Natura* as a means of best understanding the concept of the atom in that period of history. In the present study, this work has been the basic resource offered to the prospective teachers in their approach to the atom through observation and collecting evidence from nature.

The research included the discussion of instruction about the atom, starting from the atomistic philosophy of antiquity and moving up to the atomic theory of the present, using the teaching modules that were created for this purpose. Thus, important observations and experiments revolving around the concept of the atom over the course of history formed the basic framework of the teaching modules. In the literature, the concept of the atom is most prominently treated through the Modern Theories of the Atom of Dalton, Thomson, Rutherford and Bohr, respectively (Harrison and Treagust, 2000; Niaz, 1998; Niaz, Aguilera, Maza and Liendo, 2002; Peleg and Baram-

Tsabari, 2011; Petri and Niedderer, 1998; Rodriguez and Niaz, 2004; Tsaparlis, 1997; Wheeldon, 2011; Viana and Porto, 2009). By emphasizing the historical process in teaching about the atom, the importance of learning about the atom has been stressed (Ben-Zvi, Eylon and Silberstein, 1986; Blanco and Niaz, 1998; Niaz, Aguilera, Maza and Liendo, 2002; Nussbaum, 2005).

This study has taken into consideration all previous research but its teaching technique differs from what is seen in the literature. It can be seen that teaching about the concept of the atom has mostly involved using models and modeling to treat the theories of the atom that appeared after Dalton. For example, modeling has frequently been used with regard to Dalton, Thomson, Rutherford, Bohr and the Quantum mechanics model (Adbo and Taber, 2009; Justi and Gilbert, 2000; Mozzer and Justi, 2012; Niaz, Aguilera, Maza, and Liendo, 2002; Wheeldon, 2011). Although modeling-based teaching appears to be an effective method, it has its limitations. For example, students may not be able to associate the models with objects and concepts in the same way their teachers and scientists have used the models in order to call attention to similarities. They may not be able to draw the right conclusions from models that they themselves did not put together or experience or, the conflicting structures of some models may not be discernible by inexperienced eyes (Harrison and Treagust, 2000). Most important, many misconceptions may emerge from teaching with a model due to surface learning. Some studies that support this view hold, that teaching approaches other than those based on modeling are better suited for encouraging students to develop their own mental conceptions (Adbo and Taber, 2009).

As it has been seen, mental conceptualizations are not altogether rejected in the study. It is undoubtedly necessary for individuals to create a mental model in their minds in response to what they have learned. The study needed to address the criticism about how, in current educational programs, individuals are presented with atomic models that have been produced by others (scientists, teachers, peers, etc.). For that reason, the teaching modules that provide an alternative to model-based teaching focus on observation and experimentation. For example, the first module is presented using a typical observational process to set forth observations, arguments and inquiries regarding natural phenomena related to the atomistic philosophy of antiquity. Later, the concept of the atom is rediscovered over the course of history and brought into the classroom environment with consecutive experiments and observations. Thus, the observations and experiments make it possible to perceive and even make visible the concept of the atom that was at first set forth only schematically. The importance of observations and experimentation in the production of scientific knowledge and in the evaluation of scientific knowledge is indisputable. For example, prominent thinkers such as Galileo and Newton focused on observations and experiments when they were producing scientific knowledge. Again, in this study, as Lacine (1999) reported in his research, an attempt was made to carry the atom, through observations and experiments, from the schematic world along the shores of the Miletus of 2500 years ago to the visible world of today, with the help of elaborate microscopes. Being able to access observational data and results in this way, students have captured the opportunity to learn a great deal about what is known about the atom. The formation of a mental conceptualization as a result of making a synthesis of the knowledge gained after the instruction is a natural consequence. The important thing is that a custom- or ready-made model of what has been learned following the instruction does not restrict the individual's mental model.

Conclusions and Implications

This study sought to start off with selected texts of the ancients, travelling through history to the thoughts about the atom in the contemporary world, teaching the concept of the atom along the way. The study provided an integrated and comprehensive perspective on learning about the concept of the atom, an approach that included the atomistic thoughts of the ancients. Students felt the excitement of finding out something new and producing something about the atom every week. In this process, the students used inquiry-based activities that were developed from simple materials to stimulate their interest and curiosity. The students had the opportunity to inquire about the contribution of their own region to science and how the political, economic and natural phenomena in the region affected science, questioning at the same time the transfer of science across cultures. In discussing the atom, they also learned about the power of science in the societies it reaches in every era and also about the history of atomic thought.

Moreover, the study approached the concept of the atom not from the perspective of a teaching model but through observations and experiments. What is more; the study offers science-based teaching modules made up of experiments and activities that can easily be used in many environments. The activities developed can be examined by curriculum development experts and considered as introductory material that may be included in textbooks, as well as integrated into science fairs, science camps and other education-related organized events.

The concept of the atom is a precursor to understanding many aspects of science and for this reason; the topic of the atom was approached from an interdisciplinary viewpoint. Finally, the study devised a two-tier multiple-choice test on the concept of the atom as a contribution to the literature. But still the academic tracking test developed for the study can be applied as a whole or in parts to different sample groups, to larger groups, or may be tested in different studies, revised or further developed.

Alternative concepts about the atom that have not appeared in the literature up to date are reported in this study. For the future studies, the instruction using the developed modules has been evaluated quantitatively to a great degree but qualitative methods can also be used and more detailed data obtained to assess the effect of the instruction process and the activities in the modules on students' views. Thus, alternative concepts that students have, that are hard to dispel can be identified and an attempt can be made to eliminate these.

Acknowledgement

This research has funded from Mugla Sıtkı Kocman University Scientific Research Projects Programme under Grant Agreement No. BAP-2012/77.

References

Adbo, K., & Taber, K. S. (2009). Learners' mental models of the particle nature of matter: A study of 16-year-old Swedish science students. *International Journal of Science Education, 31* (6), 757-786. doi: 10.1080/09500690701799383.

Albanese, A., & Vicentini, M. (1997). Why do we believe that an atom is colourless? Reflections about the teaching of the particle model. *Science & Education, 6* (3), 251-261. doi: 10.1023/a:1017933500475.

Baine, T. (2007). *Antimatter teaching module.* Retrieved 23.04.2013, from CERN Education website: http://education.web.cern.ch/education/Chapter2/Teaching/atm.html.

Ben-Zvi, R., Eylon, B.S., & Silberstein, J. (1986). Is an atom of copper malleable? *Journal of Chemical Education, 63* (1), 64. doi: 10.1021/ed063p64

Berkheimer, G. D., Anderson, C. W., & Blakeslee, T. D. (1988). *Matter and molecules teacher's guide: Activity book* (Occasional paper No: 122). East Lansing: Michigan State University, Institute for Research on Teaching.

Blanco, R., & Niaz, M. (1998). Baroque tower on a Gothic base: A Lakatosian reconstruction of students' and teachers' understanding of structure of the atom. *Science & Education*, *7* (4), 327-360.

Bogaard P. A. (2012). Ancient theories of chemical substance, In R. Hendry, P. Needham & A. Woody (Ed.), *Handbook of the Philosophy of Science. Volume 6: Philosophy of Chemistry* (pp. 179-189). London: Elsevier Academic Press. doi:10.1016/B978-0-444-51675-6.50017-7.

Bunge, M. (2003). Twenty-five centuries of quantum physics: From Pythagoras to us, and from subjectivism to realism. *Science & Education, 12* (5-6), 445-466. doi: 10.1023/a:1025336332476.

Capelle, W. (2006). *Sokrates'ten once felsefe* (O. Ozugul, Trans.). Istanbul: Pencere Yayınlari.

Chandra, S. (2008). Demonstrating ions. *New Zealand Science Teacher, 117*, 42.

Chandrasegarana, A. L., Treagust, D. F., & Mocerino, M. (2007). The development of a two-tier multiple-choice diagnostic instrument for evaluating secondary school students' ability to describe and explain chemical reactions using multiple levels of representation. *Chemistry Education Research and Practice, 8* (3), 293-307.

Chu, H. E., Treagust, D. F., & Chandrasegaran, A. L. (2009). A stratified study of students' understanding of basic optics concepts in different contexts using two-tier multiple-choice items. *Research in Science & Technological Education, 27* (3), 253-265. doi: 10.1080/02635140903162553.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education*. Taylor & Francis e-Library.

Cokelez, A., & Dumon, A. (2005). Atom and molecule: upper secondary school French students' representations in longterm memory. *Chemistry Education Research and Practice*, *6* (3), 119-135.

Colekez, A., & Yalcin, S. (2012). Ilkogretim 7. sinif ogrencilerinin atom kavrami ile ilgili zihinsel modellerinin incelenmesi. *Ilkogretim Online*, *11* (2), 452-471.

Cros, D., Mauvan, M., Chastrette, M., Leher, J., & Fayol, M. (1986). Conceptions of first year university students of the constituents of matter and the notions of acids and bases. *European Journal of Science Education, 8* (3), 305-313.

De Posada, J.M. (1997). Conceptions of high school students concerning the internal structure of metals and their electric conduction: Structure and evolution. *Sci. Ed.*, *81*(4), 445–467. doi: 10.1002/(SICI)1098-237X(199707)81:4<445::AID-SCE5>3.0.CO;2-C

De Vos, W., & Verdonk, A. H. (1987). A new road to reactions. Part 4. The substance and its molecules. *Journal of Chemical Education, 64*(8), 692. doi: 10.1021/ed064p692.

Eyupoglu, I. Z. (2001). *Lucretius'un Sorunlari, IN: Lucretius Carus, Varligin Yapisi I,* (İ.Z. Eyupoglu Trans.), Cumhuriyet Yayınlari, Dunya Klasikleri Dizisi, no. 142, 18-25.

Field, A. (2005). *Discovering statistics using SPSS* (2nd ed.). London: Sage Publications.

Gilbert, J. (2004). Models and modelling: Routes to more authentic science education. *International Journal of Science and Mathematics Education, 2* (2), 115-130. doi: 10.1007/s10763-004-3186-4.

Gilbert, J. K., & Watts, D. M. (1983). Concepts, misconceptions and alternative conceptions: Changing perspectives in science education. *Studies in Science Education, 10* (1), 61-98. doi: 10.1080/03057268308559905.

Griffiths, A. K., & Preston, K. R. (1992). Grade-12 students' misconceptions relating to fundamental characteristics of atoms and molecules. *Journal of Research in Science Teaching, 29* (6), 611-628. doi: 10.1002/tea.3660290609.

Harrison, A. G., & Treagust, D. F. (1996). Secondary students' mental models of atoms and molecules: Implications for teaching chemistry. *Science Education, 80* (5), 509-534. doi: 10.1002/(sici)1098-237x(199609)80:5<509::aid-sce2>3.0.co;2-f.

Harrison, A. G., & Treagust, D. F. (2000). Learning about atoms, molecules, and chemical bonds: A case study of multiple-model use in grade 11 chemistry. *Science Education, 84* (3), 352-381. doi: 10.1002/(sici)1098-237x(200005)84:3<352::aid-sce3>3.0.co;2-j.

Justi, R., & Gilbert, J. (2000). History and philosophy of science through models: Some challenges in the case of 'the atom'. *International Journal of Science Education, 22* (9), 993-1009. doi: 10.1080/095006900416875.

Kaya, A. (2010). Fen bilgisi ogretmen adaylarinin isik ve atom kavramlarini anlama seviyelerinin tespiti. *Erzincan Eğitim Fakültesi Dergisi, 12* (1), 15-37.

Kehoe, J. (1995). Basic item analysis for multiple-choice tests. *Practical Assessment, Research & Evaluation*, *4* (10). Retrieved May 23, 2013 from http://PAREonline.net/getvn.asp?v=4&n=10 .

Kind, V., (2004). *Beyond appearances: Students' misconceptions about basic chemicalideas* (2nd Edition). UK: School of Education, Durham University. Self-published; available at< http://www.chemsoc.org/pdf/LearnNet/rsc/miscon.pdf >

Lacina, A. (1999). Atom- from hypothesis to certainty. *Physics Education, 34* (6), 397–402. doi:10.1088/0031-9120/34/6/411.

Law, J. F., & Treagust, D. F. (2007). *Diagnosis of student understanding of content specific science areas using on-line two-tier diagnostic tests*. Paper presented at the Second International Conference on Science and Mathematics Education (CoSMEd 2007), Penang, Malaysia.

Matthews, M. R. (2011). Alan F. Chalmers: The scientist's atom and the philosopher's stone: How science succeeded and philosophy failed to gain knowledge of atoms. *Science & Education, 20* (2), 173-190. doi: 10.1007/s11191-010-9226-2.

Mozzer, N. B., & Justi, R. (2012). Students' pre- and post-teaching analogical reasoning when they draw their analogies. *International Journal of Science Education, 34*(3), 429-458. doi: 10.1080/09500693.2011.593202.

Niaz, M. (1998). From cathode rays to alpha particles to quantum of action: A rational reconstruction of structure of the atom and its implications for chemistry textbooks. *Science Education, 82* (5), 527-552.

Niaz, M., Aguilera, D., Maza, A., & Liendo, G. (2002). Arguments, contradictions, resistances, and conceptual change in students' understanding of atomic structure. *Science Education, 86* (4), 505-525. doi: 10.1002/sce.10035.

Novick, S., & Nussbaum, J. (1978). Junior high school pupils' understanding of the particulate nature of matter: An interview study. *Science Education, 62* (3), 273-281. doi: 10.1002/sce.3730620303.

Nunally, J. C., & Bernstein, I. H. (1994). *Psychometric theory.* New York: McGraw-Hill.

Nussbaum, J. (2005). History and philosophy of science and the preparation for constructivist teaching: The case of particle theory. In J. J. Mintzes, J. H. Wandersee & J. D. Novak (Ed.), *Teaching Science for Understanding: A Human Constructivist View* (pp. 165-194). London: Elsevier Academic Press.

Osborne, R. J., & Cosgrove, M. M. (1983). Children's conceptions of the changes of state of water. *Journal of Research in Science Teaching, 20* (9), 825-838. doi: 10.1002/tea.3660200905.

Pallant, J. (2007). *SPSS survival manual, A step by step guide to data analysis using SPSS for windows* (1st ed.). New York: McGraw-Hill Education, Open University Press.

Park, E. J., & Light, G. (2009). Identifying atomic structure as a threshold concept: Student mental models. *International Journal of Science Education*, *31* (2), 233-258.

Pauri, M. (2003). Don't ask Pythagoras about the quantum. *Science & Education, 12* (5-6), 467-477. doi: 10.1023/a:1025330129744.

Peleg, R., & Baram-Tsabari, A. (2011). Atom surprise: Using theatre in primary science education. *Journal of Science Education and Technology, 20* (5), 508-524. doi: 10.1007/s10956-011-9299-y.

Peterson, R. F., Treagust, D. F., & Garnett, P. (1986). Identification of secondary students' misconceptions of covalent bonding and structure concepts using a diagnostic instrument. *Research in Science Education, 16* (1), 40-48.

Petri, J., & Niedderer, H. (1998). A learning pathway in high-school level quantum atomic physics. *International Journal of Science Education, 20* (9), 1075-1088. doi: 10.1080/0950069980200905.

Rodríguez, M., & Niaz, M. (2004). A reconstruction of structure of the atom and its implications for general physics textbooks: A history and philosophy of science perspective. *Journal of Science Education and Technology, 13* (3), 409-424. doi: 10.1023/B:JOST.0000045468.49500.3b.

Sarigollu, A. (1973). *Lucretius ve Eseri*. Ankara: Yariacik Cezaevi Matbaası.

Schmidt, H. J., Baumgärtner, T., & Eybe, H. (2003). Changing ideas about the periodic table of elements and students' alternative concepts of isotopes and allotropes. *Journal of Research in Science Teaching, 40* (3), 257-277. doi: 10.1002/tea.10076.

Sewell, A. (2002). Cells and atoms - Are they related? *Australian Science Teachers' Journal, 48* (2), 26-30.

Stefani, C., & Tsaparlis, G. (2009). Students' levels of explanations, models, and misconceptions in basic quantum chemistry: A phenomenographic study. *Journal of Research in Science Teaching, 46* (5), 520-536. doi: 10.1002/tea.20279.

Taber, K. S. (2005). Learning quanta: Barriers to stimulating transitions in student understanding of orbital ideas. *Science Education, 89* (1), 94-116. doi: 10.1002/sce.20038.

ISSN 1648–3898

Taber, K. S. (2003). The atom in the chemistry curriculum: fundamental concept, teaching model or epistemological obstacle?. *Foundations of Chemistry*, *5* (1), 43-84.
Thagard, P., & Toombs, E. (2005). Atoms, categorization and conceptual change. In H. Cohen & L. Claire (Ed.), *Handbook of Categorization in Cognitive Science* (pp. 243-254). London: Elsevier Ltd.
Treagust, D. F. (1988). Development and use of diagnostic tests to evaluate students' misconceptions in science. *International Journal of Science Education, 10* (2), 159-169. doi: 10.1080/0950069880100204.
Tsaparlis, G. (1997). Atomic orbitals, molecular orbitals and related concepts: Conceptual difficulties among chemistry students. *Research in Science Education, 27* (2), 271-287. doi: 10.1007/bf02461321.
Viana, H. E. B., & Porto, P. A. (2009). The development of Dalton's atomic theory as a case study in the history of science: Reflections for educators in chemistry. *Science & Education, 19* (1), 75-90. doi: 10.1007/s11191-008-9182-2.
Wheeldon, R. (2011). Examining pre-service teachers' use of atomic models in explaining subsequent ionisation energy values. *Journal of Science Education and Technology, 21* (3), 403-422. doi: 10.1007/s10956-011-9333-0.

Appendix - Two-Tier Multiple-Choice Test

1. Coal is made up of carbon atoms; when coal is smashed with a hammer, the carbon atoms are broken up.

a. Right

b. Wrong

c. I don't know

Because:

a. Carbon atoms do not go through any kind of change of form.

b. The collision makes the size of the atoms change.

c. When matter is smashed, atoms are smashed too.

d. Some of the carbon atoms break up into small pieces and fall off and so these atoms get smaller.

e. Other...

2. Ethyl alcohol in an open-lidded cup will reduce and turn into gas with time at room temperature.

a. Right

b. Wrong

c. I don't know

Because:

a. The diminished part of liquid ethyl alcohol will dissipate into the environment in the form of air.

b. Ethyl alcohol separates into hydrogen, oxygen and carbon atoms and transforms into gas.

c. Ethyl alcohol molecules expand under the effect of room temperature; they grow and become lighter, moving away from the environment.

d. The diminished part of the ethyl alcohol dissipated into the environment as evaporated ethyl alcohol.

e. Other …………………………………………………………………….

3. An atom is abstract.

a. Right

b. Wrong

c. I don't know

Because:

a. Atoms are models in the minds of scientists.

b. Atoms are abstract because they are not matter.

c. Atoms cannot be seen, it is only believed that they exist.

d. Atoms can be seen and measured since they exist in sizes of mass or volume.

e. Other...

4. Atoms are all the same size.

a. Right

b. Wrong

c. I don’t know

Because:

a. An atom’s number of protons, neutrons and electrons determine its size.

b. There is only one type of atom in the universe and its size is always the same.

c. The number of an atom’s protons determines its size.

d. The size of atoms depends upon the variation in temperature.

e. Other...

5. An atom is not alive.

a) Right

b) Wrong

c) I don’t know

Because:

a) Atoms are divisible and they can grow.

b) Atoms do not carry the property of being alive.

c) Atoms are alive because they move.

d) The atoms of living organisms are alive.

e) Other: ………………………………………………………………………………

6. Atoms are in the shape of a sphere.

a) Right

b) Wrong

c) I don’t know

Because:

a) Atoms can be in different shapes depending upon their type.

b) Atoms are just like marbles; they are spheres that are solid inside.

c) Atoms appear to be flat like galaxies.

d) An atom is represented by a lot of points (circles).

e) Other:...

7. When a fast-moving train collides with atoms in the air, it breaks the atoms up and continues on its way.

a) Right

b) Wrong

c) I don’t know

ISSN 1648–3898

Because:

a) At the moment they collide, the atom's outer shells protect the atom.

b) Air is flexible so therefore atoms are flexible too.

c) Atoms are hard; they cannot be broken up.

d) There would be no change in the shape of the atoms after the collision.

e) Other:...

8. Water molecules that change from the solid state (ice) into liquid get smaller.

a) Right

b) Wrong

c) I don't know

Because:

- a) In the change of state, a part of the hydrogen evaporates and moves away and the water molecules get smaller.
- b) During the change of state, the ice breaks up into pieces and converts into little water molecules.
- c) The size of molecules doesn't change during the change of state.
- d) In the change of state, the atoms of hydrogen and oxygen that make up water divide up and form small molecules.
- e) Other:...

9. A single atom is colorless.

a) Right

b) Wrong

c) I don't know

Because:

a) The whole of matter and a single atom are the same color.

b) When atoms are by themselves we cannot speak of a particular color.

c) Opaque materials have opaque atoms.

d) Atoms have a metallic color.

e) Other:...

10. The atom has to be broken up to break away the electron.

a) Right

b) Wrong

c) I don't know

Because:

a) Electrons can be broken off from atoms without breaking up the atom.

b) An atom is made up of protons, electrons and neutrons. The breaking away of any one of these is the division of the atom.

c) Because one of the basic building blocks of the atom is the electron, when electrons are broken off, this leads to the division of the atom.

d) Electrons cannot be broken off from an atom in any way.

e) Other:...

11. We can't see atoms.

a) Right

b) Wrong

c) I don't know

Because:

a) Atoms are big enough to see under the microscope.

b) Atoms can't be seen, we can only believe in their existence.

c) We can see atoms with the naked eye.

d) We can see atoms with scanning tunneling microscopes.

e) Other:...

12. We can obtain different elements only with radioactive reactions.

a) Right

b) Wrong

c) I don't know

Because:

a) Sunlight makes atoms change and transform into one another.

b) Unstable atoms can turn into other atoms.

c) Every atom's protons, neutrons and electrons are unique.

d) Atoms can convert into each other through phenomena such as thunder and lightning.

e) Other:...

13. Atoms don't move in matter in the solid state.

a) Right

b) Wrong

c) I don't know

Because:

a) They vibrate.

b) Because there are no spaces in between the particles of solids, they cannot move.

c) They can't move because they're hard.

d) Only electrons move in an orbit.

e) Other:...

14. Atoms expand when their energy increases.

a) Right

b) Wrong

c) I don't know

Because:

a) The distance between atoms and the vibration increases.

b) The electrons move away from the nucleus and the volume of the atom increases.

c) Matter itself expands.

d) The nucleus of the atom will expand.

ISSN 1648–3898

e) Other:...

15. The masses of all atoms are the same.

a) Right

b) Wrong

c) I don't know

Because:

a) Air does not have a mass.

b) The mass of an atom depends on how many atoms it's made up of.

c) All atoms are particles with equal masses.

d) All atoms do not have equal mass numbers (the same number of protons and neutrons).

e) Other:...

16. Matter can be divided into infinity without losing its properties.

a) Right

b) Wrong

c) I don't know

Because:

a) Matter is continuous.

b) Matter can be divided into sub-atomic particles.

c) Matter can be divided until "there is nothing left."

d) Matter can be divided until only a single atom is left with its own properties.

e) Other:...

17. In electrical current, the atoms of matter are carried from one place to another.

a) Right

b) Wrong

c) I don't know

Because:

a) In solids, only free electrons move.

b) Electrical currents in solutions are caused by atoms changing places.

c) Negatively charged electrons flow into the spaces where there are more positively charged atom nuclei.

d) Electrons are particles that conduct electricity.

e) Other:...

18. A single gold atom displays all of the properties that one mol of a gold atom displays.

a) Right

b) Wrong

c) I don't know

Because:

a) Soft matter cannot be made of hard molecules.

b) A single atom does not have the same properties as the whole of matter.

c) All of the atoms in a molecule are the same.

d) Matter is made up of atoms and matter in between those atoms.

e) Other:...

19. Molecules are made of atoms and forces of attractions keep them together.

a) Right

b) Wrong

c) I don't know

Because:

a) There is matter that occupies the spaces between atoms.

b) Atoms have bonds that tie them to each other.

c) There are only atoms.

d) Molecules are only space and they stick together because of the force of attraction of the atoms.

e) Other:...

20. Electrons orbit around atoms as in the solar system.

a) Right

b) Wrong

c) I don't know

Because:

a) According to modern atomic theory, electrons are on electron clouds around the nucleus and their places are determined by chance.

b) Electrons revolve around themselves in spaces that suit their own level of energy.

c) Electrons exist in orbits that are like the rings in the solar system.

d) Protons attract electrons and electrons are fixed in one specific place.

e) Other:...

21.The bubbles in boiling water are the gases H_2 and O_2.

a) Right

b) Wrong

c) I don't know

Because:

a) When water boils, the water molecules turn into air molecules.

b) When water boils, the water separates into its components.

c) The bubbles that are emitted are clusters of evaporated water.

d) O_2 and H_2 dissolved in water move away from the environment.

e) Other:..

22. Matter is made up of atoms.

a) Right

b) Wrong

c) I don't know

Because:

a) Atoms are the most fundamental form of matter; the cell is the most fundamental form of a living being.

b) Matter has another piece of matter in-between that wraps around the atoms.

c) Living beings have atoms but living beings are not matter.

d) When we look into matter with a very developed magnifying instrument, we will see that it is only made of atoms.

e) Other:..

23. When you take out all of the atoms in this piece of paper, you're still left with a piece of paper.

a) Right

b) Wrong

c) I don't know

Because:

a) A little bit of dust is left.

b) Nothing is left.

c) A little piece of paper is left but its weight is reduced.

d) Energy is left.

e) Other:...

Received: *September 27, 2014* Accepted: *January 08, 2015*

Ayse Oguz Unver	PhD. Associate Professor, Mugla Sitki Kocman University, Faculty of Education, Science Education Department, Mugla, Turkey. Phone: +90 543 448 8939; Fax: +90 252 223 8491. E-mail address: ayseoguz@mu.edu.tr Website: www.mubem.mu.edu.tr
Sertac Arabacioglu	MA. Research Asistant, Mugla Sitki Kocman University, Faculty of Education, Science Education Department, Mugla, Turkey. E-mail address: sertacarabacioglu@mu.edu.tr