

THE ATTITUDE OF ENGINEERING FRESHMEN TOWARDS CHEMISTRY TEACHING IN TURKEY

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ABSTRACT:

Although chemistry keeps an important place in the science curricula of primary and secondary educations, students typically leave high school with misunderstandings about the nature of matter, chemical processes, and chemical world.

This study aims to identify the attitudes of engineering freshmen towards chemistry in Turkey. It also tries to identify classifications and examples of matter, commonly used by chemistry teachers in secondary schools; those are likely to be misunderstood by students. It offers teachers some suggestions contributing to raise their students' awareness of learning chemistry.

ÖZET:

İlköğretim ve ortaöğretim fen müfredatlarında kimya önemli bir yer tutumakla birlikte, öğrenciler maddenin doğası, kimyasal süreçler ve kimya dünyası hakkında genellikle yanlış kavrayışlarla liseden mezun olmaktadır.

Bu çalışma, Türkiye’de mühendislik birinci sınıf öğrencilerinin kimya ile ilgili yaklaşımlarının belirlenmesini amaçlamaktadır. Ortaöğretimde kimya öğretmenlerinin sıklıkla kullandığı, öğrencilerin yanlış anlaması olası olan madde ile ilgili sınıflandırma ve örnekler belirlenmeye çalışılmıştır. Çalışma, kimya öğreniminde öğrencilerin farkındalık düzeyinin yükseltilmesinde öğretmenlere yardımcı olacak bazı önerileri de ele almaktadır.

Key words: *High School Chemistry, First-Year Undergraduate, Chemical Education Research, Misconceptions, Student-Centered Learning*

1. Introduction

Learning styles are the ways that students characteristically take in and process new information. Students function in a variety of different ways in learning situations [1-3]. For all countries, the improvement of educational programs is increasingly becoming more important. The rapidly growing bodies of knowledge should be put into well organized frameworks, and the learner’s potential to learn meaningfully should be considered. Traditional classroom structures need to be replaced with much more active learning approaches that new technology, pedagogy, and understanding of human learning facilitate.

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1.1. Aim of the present study

In Turkey, schooling consists of three main components: compulsory basic education (age 6-14; 8 years), secondary education (age 14-18, 4 years), and higher education.

The elementary teaching of chemistry begins with a brief introduction of physical and chemical changes at the age of 10 as the part of the science courses. Chemistry courses start with the properties of matter in the secondary education at the age of fourteen [4].

The current study aims to identify the opinions and attitudes of engineering freshmen towards chemistry in Turkey. It also tries to identify classifications and examples of matter, commonly used by chemistry teachers in secondary schools; those are likely to be misunderstood by students. It offers secondary school and university chemistry teachers some suggestions contributing to raise their students' awareness of learning problems and difficulties concerning matter transformations.

It addresses the problem with the use of a conceptual approach that incorporates a number of solution strategies such as the use of models helping the students to understand the basic concepts and with the active use of electronic media and internet to improve instruction in chemistry. The study has been guided by educational literature, and feedback obtained over four years from engineering students at the beginning and at the end of the general chemistry course.

1.2. Review of the related chemistry education literature

Recently, how students learn and how they think about their learning has become a very important area of research for chemical educators [5-12].

The results of the research about learning science in general imply that the students consider scientific knowledge as a fix immutable collection of non-related facts and formulas that have little connection to the real world. Their role as students consists in memorizing the facts and formulas and reproducing them during exams. Thus, students tend to be passive learners. In case of chemistry learning, they usually do not use their conceptual knowledge of chemistry to analyze the problem situation qualitatively. They don't reason the chemical fact asked or question the result obtained. They live and operate in the macroscopic world of matter, but they do not perceive chemistry as related to their surroundings. Moreover, they do not easily follow shifts between the macroscopic and microscopic levels. Students find the chemical concepts very abstract and they do not explain chemical phenomena easily by using these concepts [13-22].

Chemistry education research focuses on understanding and improving

chemistry learning by studying variables relating to chemistry content, and also to what the teacher and student do in a learning environment. As the population of any society becomes more heterogeneous and as researchers learn more about how students gain knowledge, who have dissimilar backgrounds, learning styles, and ability; the configuration of chemistry content becomes increasingly important [14, 23].

Preconceptions in chemistry, as in physics, are extremely persistent. Authors describing the evolution of preconceptions described a rapid evolution in fundamental ideas about chemistry between the ages of 6 and 12, but only very slow change thereafter, in spite of intensive instruction in chemistry. Thus misconceptions present at age 12 are likely to still be present in 12th grade or in college freshmen [11, 16, 24]. Various studies indicate that some students enter university, and even, graduate school, with incorrect chemical concepts [25, 26].

Chemistry education research has made considerable progress in identifying common preconceptions and misconceptions of middle school, high school and university students in chemistry [27]. There may be several external factors that can generate students' misconceptions. Some studies concluded that students actively rejected the use of scientific vocabulary in favor of daily speech, which led them into many misunderstandings [5, 28 -30]. Many authors observed the ways in which students confuse models and images with reality, and the ways in which concepts misunderstood in earlier grades form the meaningful and coherent alternative framework of later misconceptions [31, 32]. Some authors ask how often such misconceptions are generated by teachers; and which teaching strategies can help students' understanding of these concepts. Teachers themselves may have misconceptions regarding scientific concepts and models [33, 34].

When the teachers were asked to answer some questions which predominantly involved translating between macroscopic, microscopic, and symbolic representations of chemistry, their most commonly incorrect items and misconceptions were found interestingly in the similar distribution with students [35]. When potential origins of the teachers' misconceptions were explored, it was observed that teachers were lack of awareness of their own misconceptions, and teachers' misconceptions were directly transmitted to students. Education researchers advice teachers to have a clear and comprehensive view of the nature of a model in general. They also advice teachers to understand their students' mental models evaluate their own way of introducing scientific models; develop good teaching models and conduct modeling activities effectively in their classes. They conclude if teachers are not well prepared, their students cannot be expected to be successful in applying scientific concepts in solving problems [36].

2. Methodology

This investigation had continued for four years. The questionnaire was conducted to 410 freshman engineering students between 2001 – 2005 academic years at the beginning of the general chemistry course, and then at the end of the course some of the questions present in the questionnaire were reasked as a part of the final examination.

The questionnaire was designed to assess students' knowledge and reasoning about chemistry, to address their previous experiences and their attitude towards the chemistry subject, to get their opinions and proposals on chemistry teaching in secondary schools. It consists of fourteen questions which are true-false type, yes or no type, and open ended type.

The freshman engineering students, who answered the questionnaire, had already met with the microscopic and macroscopic explanations of matter three times, namely in primary school, in middle school and in high school. Also, they succeeded in the central university entering examination, in which 14 chemistry questions took place. They ranked in 2 % of about 1.7 million candidates who applied for the university entering examination that year.

3. Results

Tables 1 to 5 show the results of the questionnaire which had been applied for four academic years to the engineering freshmen. True or false type questions (Q1, Q2) of Table 1, and yes or no type questions (Q3, Q4) of Table 2, check students' knowledge and reasoning of chemistry. Those first four questions also check the students for the degree of relating the chemistry knowledge with the real world.

Q1 asks if freezing of milk is a physical process. Examples from correct answers to Q1 are as follows: *"It is a physical change, since the chemical composition is the same in both liquid and solid states/ there is no chemical change during melting and freezing, only physical state changes /freezing is physical."*, and the wrong answer examples: *"the freezing of milk is chemical/ the freezing of milk never occurs /phase change is a chemical process."* Q2 asks if souring of milk is a chemical change. For Q2 some chosen correct answers are as: *"It is a chemical change, since compounds in milk such as proteins, fats, vitamins are changed into other chemical substances by microorganisms / souring is a kind of fermentation which produces new substances / oxidations such as souring and rusting are chemical events."* More than 80 % of students answered Q1 and Q2 correctly.

Table 1. True-false questions about students' knowledge and reasoning of chemistry in the questionnaire

True or False Statements	True %	False %	No idea %
1. Freezing of milk is a physical change.(TRUE)	90.0	6.0	4.0
Probable answer: It is true, since it has the same chemical properties in both solid and liquid states.			
2. Souring of milk is a chemical change. (TRUE)	True %	False %	No idea %
	87.0	6.0	7.0
Probable answer: Souring of milk is an irreversible chemical change.			

As seen from Table 2, fifty three percent and thirty seven percent of the students respectively could not give right answers to Q3 and Q4 which are asking some basic chemistry concepts indirectly.

Q3 asks if butter is a pure substance. Students knowing the correct answer stated that: *"It is not pure, since it is the mixture of proteins, fats, vitamins and carbohydrates / it can be separated into its components by physical methods /it does not have distinct formula."* On the other hand, students who assumed butter as pure gave explanations like: *"It is pure, since it has certain melting and freezing points/ it does not decompose into other substances / its density is constant throughout/ it is produced from milk / there are two kinds of butter:one is daily life butter which contains salt and some sweeteners; and the other is 'butter of experiments' which is pure."* The students, assuming butter as a pure substance in Q3, regarded it as a food not as a chemical mixture.

Q4 asks if there is any atom in the human body. Right answers are such as: *"The proteins, for example, contain C, H, N, O atoms/ all living and nonliving things are made up of atoms/ as remembering from biology, there are atoms such as Mg, S, and Fe."* Wrong answers are as follows: *"Have no idea/ there are cells in our body, not atoms / the smallest particle in matter is an atom, but in living systems it is a cell/ nonliving things contain atoms, but living things do not."* The students, answering Q4 wrongly, 37 %, reasoned that the smallest particle in a substance is an atom but the smallest particle in human body is a cell.

Table 2. Yes or no questions about students' knowledge and reasoning of chemistry in the questionnaire

Yes or No Questions	Yes %	No %	No idea %
3. Is butter a pure substance or not? (NO)			
At the beginning of the semester	53.0	29.0	18.0
At the end of semester	2.0	95.0	3.0
Probable answer: Butter is a mixture, it is not pure. When we melt it we can see the different phases of matter such as fat and water.			
4.Is there any atom in the human body ?(YES)	Yes %	No %	No idea %
	63.0	17.0	20.0
Probable answer: All the molecules in the body are composed of atoms of elements.			

These results imply that students compared and confused an atom with a cell in a living system. These findings are parallel to the previous studies. The students live and operate in the macroscopic world of matter; but they do not easily perceive chemistry as related to their surroundings. Moreover, they do not easily follow shifts between the macroscopic and microscopic levels [13, 14, 37].

In Table 3, there are three open ended questions (Q5-Q7) which inspect students' explanations about more advanced and conceptual topics of chemistry. In Q5, students are expected to make a distinction between iron-sulfur mixture and iron sulfide compound. During middle school education and high school education in Turkey, the physical change and chemical change differences, specifically the iron-sulfur mixture example has been taught repeatedly. So, the students are mostly assumed to remind that the magnetic property of iron (Fe) is used to distinguish the iron and sulfur mixture from the compound of iron sulfide, in which Fe loses its magnetic property. Only 27 % of the answers were correct and explained the reason properly. Some right answers are as: *"Iron and sulfur form an heterogeneous mixture, they keep their own properties.They can be separated by using a magnet. But in iron sulfide there is a chemical bonding, elements can not exhibit their own properties./ Iron sulfide formation is a chemical change; it can not be separated by physical methods./ Iron is electrically conductive, but iron sulfide is not."* Fifty one percent of the students answered wrongly and twenty two percent of those declared that they had no idea about iron and sulfur mixture. Some wrong answers are as : *"we can see the difference by touching or by eye /with chemical indicators / the difference can be seen by the naked eye /we can not understand"* Although teachers

usually try to compare physical changes and chemical changes using examples from the macroscopic properties such as the magnetic property of Iron, the findings show that students do not always understand the examples of the macroscopic world that is assumed clear by the teacher as Coll and Treagust stated previously[38].

Table 3. Open ended questions about students' knowledge and reasoning of chemistry in the questionnaire

Open Ended Questions	Right %	Wrong %	No idea %
5. Iron sulfide is produced by heating iron and sulfur together. How do you differentiate iron-sulfur mixture from iron sulfide compound?	27.0	51.0	22.0
Correct answer: When we hold a magnet near the iron-sulfur mixture, iron will be attracted by the magnet; but the iron sulfide compound is not attracted by the magnet.			
6. Density of alcohol is 0.8 g/cm ³ and density of water is 1.0 g/cm ³ . Does 100 g of alcohol or 100 g of water have greater volume? Why?	Right %	Wrong %	No idea %
	62.0	26.0	12.0
Correct answer: $d = m / V$ therefore $(100/0.8) > (100/1.0)$ $V_{\text{alcohol}} > V_{\text{water}}$			
7. What is an atom?	Right %	Wrong %	No idea %
	90.0	5.0	5.0
Correct answer: The smallest particle which represents an element.			

Q6 asks students to compare the density of alcohol with the density of water. It tests students' knowledge about the derived intensive quantity and their level of information transformation. 62 % of them gave correct answer. Some wrong answers to Q6 are listed as: *"They have the same volume. Because they have the same mass./Volume of alcohol is less, since its density is smaller./ Having different densities does not mean having different volumes./ They have the same volume. When we pour into the container, they occupy the same space."* The students giving wrong answers to Q6, 26%, had especially confused volume with mass, assuming both as the same quantity. Q7 asks the definition of an atom. The right answers are clear such as: *"The smallest particle representing the element. /An atom is the smallest particle which carries the properties of an element./ The smallest particle in an element such as H in H₂ molecule. /It comes from the Greek word atomos, which means indivisible."* The correct answer percent was very high, 91% (Table 3).

In Table 4, there are two questions (Q8, Q9) examining students' consideration about the study field and applications of chemistry. Q8 inquires the subject area of chemistry. Seventy four percent of the students described the subject of chemistry correctly as matter and energy. Twelve percent of the students had no idea about the

subject and applications of chemistry, fourteen percent of them mostly confuse chemistry with biology claiming that chemistry studies the subjects necessary for our lives / nature/ human life.

Table 4. Questions about students' idea for the study field and applications of chemistry in the questionnaire

Open Ended Questions	Right %	Wrong %	No idea %
8. What does chemistry study?	74.0	14.0	12.0
Probable correct answer: It studies matter, energy and their effects on each other.			
9. Do you think that you use the information in your life that you learnt in your previous chemistry courses ?	Right %	Wrong %	No idea %
	79.0	13.0	8.0

Keeping in mind that 37 % of the students replied Q4 wrongly, asking the presence of atoms in human body; we may say that the right answers for both Q7 and Q8 were using correctly memorized words, and the students demonstrated a shallow understanding of the key concepts such as atoms, subject of chemistry and so on.

Q9 requests from the students to tell their opinion about the benefits of learning chemistry in life. Seventy nine percent of them agreed that chemistry was really useful in life but could not explain where or how. Some explanations may be summerized as: *"Certainly I use. But I don't know how and where; adding sugar into tea, eating food, washing dishes etc; we can prepare yogurt from milk ; corrosion of iron can be prevented; I have never needed chemistry; we use water and olive oil in every day life but I do not mind their densities; we have no chemical problem in our lifes; when I was in high school, I entered a scientific competion which increased my fame among the friends; It helps me to think rationally."* Thirteen percent of them stated that they had never needed chemistry knowledge, since life was different from the chemistry. Eight percent of the students stated that they had no idea. Although they were freshmen in engineering programs, they did not assume their undergraduate education and their future professions as the part of their lives. They also did not have an idea about their responsibility as citizens to humanity about chemical substances, reactions, and processes central to their lives. These results imply that chemistry teaching in the secondary education as well as undergraduate education has got to be reconstructed in order to sustain a lifelong use of chemistry as a tool of coherent thinking. Providing students with a clear understanding of the purpose, goals, and content of a topic will help them in this manner. Moreover, students need to understand the activity's goals and what these imply about how they should respond to the activity.

Table 5. Questions about the students' previous experiences and about their attitude towards the chemistry subject

Yes or No Questions	Yes %	No %	Very Few %
10. Did you do any chemistry experiments in your high school education?	42.0	21.0	38.0
11. Which of the following visual methods did you have in your chemistry class?			
PPT presentation	25.0	75.0	
Video film	40.0	60.0	
Slide show	44.0	56.0	
Overhead transparency	46.0	54.0	
12. Did you enjoy your chemistry lessons in high school?	62.0	38.0	
13. Do you think that chemistry courses are necessary in high school education ?	89.0	11.0	
Open Ended	Similar answers %		No idea
14. How should be chemistry introduced for the beginners?	93.0 % of the students agree that starting chemistry learning with matter is easy		7.0

In Table 5, the four questions (Q10-Q13) ask the students' previous experiences and their attitude towards the chemistry subject. Q10 asks if the students do any experiment in chemistry lessons previously. Twenty one percent of them declared that they did no chemistry experiments in their high school education, and thirty eight percent of them stated that they did only a few experiments. When the answer sheets of the individual students were checked up, it was very clear that the ones who had chemistry experiments in the secondary education, 42 %, gave more precise answers to the questions than the others and presented mostly good reasons for their correct answers.

In Q11, the classroom teaching habits of their high school chemistry teachers are asked. The results illustrated that the computer aided teaching is the least with 25 % and the overhead transparency use is the most with 46 % in high school chemistry teaching in Turkey. Still, more than half of the teachers do not use any of the visual methods, namely ppt presentation, video film, slide show, overhead transparency etc. As a result of the limited use of the visual methods, the students have only a chance

of “blackboard learning”. Costa, Marques and Kempa underline that the teachers need to pay careful attention to learner differences and conceptions as they introduce different levels of chemistry to their students, and should encourage the use of multiple models for a given phenomenon [39].

Q12 asks if the students enjoy their chemistry lessons in high school. Thirty eight percent wrote that they did not enjoy their chemistry courses. Q13 asks if chemistry courses are necessary in high school education. Most of the students agreed that chemistry learning was necessary in high school, 89 %. According to the students who thought that chemistry courses are unnecessary, chemistry was not taught related to the life and industry, they were expected to know chemistry at a level of chemist, and they were not informed enough about the usage of chemistry by their teachers in high school.

Q14 requests the students to tell their opinion about the preliminary topic of chemistry learning. Most of them, 93 %, agreed that chemistry as a science can be introduced with matter as in the present curricula. Some students also emphasised that chemistry should relate to life, it must have fun, it might try to catch students by enjoying, high school chemistry curricula must contain less about ‘quantitative’ problem solving, but more about ‘qualitative’ aspects.

4. Conclusion

The results of the present study imply that students have come to the university level almost having no conceptual understanding of basic chemistry topic such as matter. They have carried memorized correct sentences in their minds, but they could not apply their knowledge to answer the simple questions of everyday life and nature.

One of the most important objectives of the high school chemistry teaching is to develop ability to use chemistry as a tool to explain the real life events. But it seems this purpose has not been achieved successfully. It is necessary to find new ways of bringing chemistry to life for students. Chemistry teachers need to emphasize new dimensions to learning chemistry and to address limited student understanding of the role of chemistry in everyday life. The results of the present study clearly show that the symbolic, macroscopic and sub-microscopic learning levels should be combined with the real world problems and their solutions as just emphasised by some investigators [40-42]. In order to build up a good network structure to teach chemistry the following clarifications can be considered and reviewed:

Explanation of the industrial processes and environmental applications through case studies, investigative projects, experimental studies, oral presentations etc. can be used to help students to become active participants in their own learning.

Reviewing the teaching methods regularly, providing students with experiences with phenomena, introducing chemistry subject explicitly, encouraging students to explain their ideas and guiding student interpretation and reasoning are also important to reach the successful learning.

As Kevin (1969), Felder and Silverman (1988), Felder and Brent (2005), Felder and Spurlin (2005) brought to light, the teachers should choose different methods and instruments of teaching, considering the learning style differences of their students. Students may be i) oriented toward facts and procedures, ii) oriented toward theories, iii) visual, verbal, active learner by trying things out, iv) enjoy working in groups, v) prefer working alone, vi) learning in small steps or vii) learning in large jumps [43-46]. Teaching according to the different learning styles can also help the individual students for understanding their learning strengths and weaknesses.

Another important tool of teaching chemistry is the wide use of the information technology and internet. Students are no longer limited to information provided by textbooks and printed materials such as worksheets. The teachers should give homeworks and term projects based on internet, therefore students will make use of internet options for their learning. Dori et al. and Cole validated that students find the Web-based chemistry courses useful and enjoyable for themselves, but chemistry teachers have various reservations as to their readiness to apply IT-enhanced teaching in their classroom [47, 48]. The teachers may construct their own 'Course-related Web pages' which will help teachers to follow their students closely and to check the accuracy of the students' perceptions of how well they teach. Students can enter their comments about the course and communicate with their instructors and with their class mates; the high quality, reliable and course related information, tests, video films and even games can be linked in the course web site. They can send questions electronically to the instructor to express a doubt or misconception that they might have been afraid to voice in class; the instructor can transmit the question and the answer simultaneously to all students. [49].

Some free of charge electronic journals are very useful for the chemistry teachers to follow the research studies about chemistry teaching and learning as well as educational technology, translating research into practice, learning theory and so on. The followings are some of the available journals via internet: The 'Chemistry Education Research and Practice' (CERP), on the website address <http://www.rsc.org/cerp>, the 'Journal of Chemical Education', on the website address <http://jchemed.chem.wisc.edu/>, the 'Turkish Online Journal of Educational Technology', on the website address <http://www.tojet.net/>, the 'Educational Sciences: Theory & Practice', on the website address <http://www.edam.com.tr/estp.asp>, the 'Ankara University Journal of Educational Sciences', on the website address

<http://www.education.ankara.edu.tr/ebfdergi/>. Besides these a well researched source of discussions about misconceptions in science exists in the web site of Science Education Misconceptions, <http://www.oise.utoronto.ca/~sciemce/> A very useful and new electronic database of studies focusing on students' difficulties in understanding specific chemistry concepts and rules can be found on the website www.card.unp.ac.za, 'CARD: Conceptual and Reasoning Difficulties'. Currently, the CARD website contains over 5000 references as well as extensive information on chemistry difficulties, and will be expanding to include other areas of science, mathematics and technology [50-54]. The teachers can also make use of audiovisual chemistry resources which are opened by the Chemistry Societies, Chemical Companies, Universities or the individual chemistry instructors.

The syllabuses of high school chemistry courses in Turkey contain a lot of topics, so that the teachers have very limited time to teach chemistry by including students in each step. It is not objectively possible to do all the advised methods mentioned above for each chapter. One should consider the chemistry course as a whole, and apply those new methods as much as possible. For example, the teacher can prepare one experiment for each chapter, can give internet based homework as a term paper, can make one exam as 'a take-home exam' which asks the solution of a real life problem such as the soil pollution, global warming etc. by using the chemistry knowledge that the students gained in their classical chemistry lectures. We should not forget that our students of today will be the citizens and professionals of tomorrow.

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