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University and Secondary School Students' Misconceptions about the Concept Of "Aromaticity" in Organic Chemistry

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Abstract: Aromaticity concept is given incorrect or incomplete to the student in secondary education and knowledge based on this basic concept has been caused to another misconception in future. How are the achievement levels relating to the comprehension of various characteristics of aromatic compounds for the first and third grade students attending Department of Chemistry in Faculty of Sciences and Arts, and Faculty of Education in Dicle University and eleventh (last) grade secondary students? Sample of this study consists of 140 students from Department of Chemistry in Faculty of Sciences and Arts, and Faculty of Education in Dicle University and 65 students randomly selected from secondary school students in Diyarbakır city center. Data were collected from the achievement test developed for aromaticity concept and features. According to the findings of this study, the average achievement scores difference between the students' relating to cyclic properties, planer structure, conjugated double bond, the reactions of aromatic compounds and aromatic compounds obeying Huckel's Rule has been found significant. It has been seen that the Aromaticity concept was given in a less amount in secondary school chemistry instruction program or even insufficient and misconceived form in some chemistry books by reviewing the last grade of secondary school chemistry text books. The findings of this study showed that the students have had misconceptions about this subject. So, the secondary school instruction program could be reviewed and given place about aromaticity concept on a large scale.

Key words: Misconception, Aromaticity, Organic Chemistry Education

INTRODUCTION

Identification and investigation of student misconceptions in chemistry education have been very important for the last two decades. Several researchers such as Stavy (1988); Peterson and Treagust (1989); Ebenezer and Gaskell (1995); Quiles-Pardo and Solaz-Portol ´es (1995); Ayas and Demirbaş (1997); Ayas and Coştu (2002); Akınoğlu and Yaşar, (2007); Akpınar, (2007); Ebenezer, (2001); Ebenezer and Gaskell, (1995); Johnson and Scott, (1991); Kabapınar, Leach and Scott, (2004); Kaartinen & Kumpulainen, (2002); Köse (2007); Taylor and Coll, (1997); Lamanauskas, Gedrovics and Raipulis (2004) in many countries have been focused on some concepts like dissolution, particulate nature of matter, chemical bonding, reaction rate, acids and bases, electrochemistry, organic chemistry, chemical equilibrium and solution chemistry.

Aromaticity and aromatic compounds form an important part of organic chemistry. If this concept is taught to the student properly starting from secondary education, most of the misconceptions can be prevented. Thus, the student understands the differences about its chemical structure and interprets the reactions of these compounds in a meaningful way when he/she distinguishes aromatic compounds from other compounds.

"Aromatic Compounds" can be defined as compounds having at least one cycle, planar geometry, conjugation in all parts and obeying Huckel's Rule. It is known that these compounds are also called "aromatic" since they have odour. This definition is not found in any secondary education text books. This concept has been stated on a small scale or insufficient form in secondary education text books. The chemistry text books taken from three secondary schools having different instruction programs have been examined and the following results were obtained:

1. It has been stated that "aromatic compound must have benzene cycle" in a Science Lycee chemistry text book (Sina, 1994). This definition is wrong because every compound having benzene cycle may be aromatic but the idea that "every aromatic compound should absolutely have benzene ring" is wrong. This concept could be given in a more detailed form in the text book. After definition of aromatic compounds, the next topic was the reactions of aromatic compounds in the text book. Nomenclature and characteristic properties of aromatic compounds are not found in the text book. If the reactions were given after aromaticity concept, the similar properties of aromatic compounds in their

reactions could be comprehended more easily. Aromatic compounds do not react in oxidation and addition reactions unlike aliphatic compounds. They give substitution reactions in special conditions. This fact has been stated in all organic chemistry text books.

2. It has been stated that "common property for aromatic hydrocarbons is having benzene cycle and Benzene can be accepted as cyclohexatrien with this structural formula" in general lycee text books (Chemistry text book , Lycee 3, 1987). The first part of the definition can be corrected for contributing to definition but the second part of the definition is completely wrong. As it is known, Benzene is 36 kcal/mole more stable than imaginary cyclohexatriene in terms of hydrogenation heats. All of these are defects because of insufficient definition. In the text book, some of the aromatic compounds' nomenclature was given shortly but the reactions of the aromatic compounds have not been mentioned. It is very difficult to comprehend this concept in this manner. The characteristic properties of an aromatic compound differentiating from aliphatic compound should be emphasized absolutely.

3. It has been seen that this concept was given on a small scale but nomenclature and reactions were given in details in the text book used for Chemistry Department of Industrial Occupation Lycee. "Aromatic compounds having cyclic structure can be obtained mostly from coal tar" expression has been seen enough in the text book (Öktemer, 1992). This definition is also insufficient. Briefly, it can be said that required care has not been showed for acquiring aromaticity concept in each three text books. This concept can be given in a correct and detailed form organizing and considering the level of the students in the light of scientific information (Solomons, 2002; Fessenden and Fessenden, 1994; Hart, Hart and Craine, 1998).

It can be said that aromaticity concept which is one of the main concept of organic chemistry should be taught to the students starting from secondary education as it can be understood from the above explanations. For this purpose, the level of acquiring aromaticity concept in secondary and university education has been investigated.

Purpose of the Study

How are the achievement levels relating to comprehending various characteristics of aromatic compounds for the first and third grade students attending Department of Chemistry in Faculty of Sciences and Arts, Faculty of Education in Dicle University and eleventh (last) grade secondary students? The following questions have been tried to answer related to main purpose expressed as above question:

Is there a statistical significance between the achievement level of the first and third grade students attending to Department of Chemistry in Faculty of Sciences and Arts, Faculty of Education in Dicle University and eleventh (last) grade secondary students related to applied achievement test in terms of; a) the characteristic of aromatic compounds having cycle, b) planar structure and conjugation, c) Huckel's Rule and d) the reactions of aromatic compounds.

1) Is there a statistical significance between the achievement level of the first and third grade students attending the Department of Chemistry in Faculty of Sciences and Arts, and Faculty of Education in Dicle University students related to applied achievement test in terms of; a) the characteristic of aromatic compounds having cycle, b) planar structure and conjugation, c) Huckel's Rule and d) the reactions of aromatic compounds.
2) Is there a statistical significance between the achievement level of the secondary school (applying different instruction program) students attending the last grade related to applied achievement test in terms of; a) the characteristic of aromatic compounds having cycle, b) planar structure and conjugation, c) Huckel's Rule and d) the reactions of aromatic compounds?

METHOD

Research method is descriptive survey method. This method is used in the researches trying to explain and describe what the events, objects, existence, institution, groups and various areas are (Kaptan, 1991:59).

Sample of the Study

Sample of the study consists of a total of 214 students from Department of Chemistry in Faculty of Sciences and Arts, and Faculty of Education in Dicle University and 65 students selected from secondary schools. Some of the students in the sample of the research were not included in statistical evaluation since they did not answer achievement test. So, statistical analyses were conducted on a total of 140 students in university level and 65 students in secondary education level. Determination and comparison of secondary and university students' misconceptions contributes the literature in terms of quality and format of misconceptions about aromaticity in different schools. These misconceptions can remain constant or change from secondary school to university and the sources of these misconceptions can vary in different schools. This study aimed that the differentiation of misconceptions about aromaticity in secondary schools and universities.

Development and Application of Data Collection Scale

The achievement test developed for "aromaticity concept and characteristic properties" as data collection scale has been used. The achievement test was prepared by the contribution of the academic staff in Department of Chemistry, Faculty of Education in Dicle University.

The test determining achievements of the students related to aromaticity concept and characteristic properties was prepared in the form of four (4) groups by considering the properties of aromatic compounds. 25 multiple choice questions were included in this test. The distribution of the questions according to the groups is as follows:

1st Group: Aromatic compound has cycle: It contains 7 multiple choice questions related to Benzene, its derivatives and differences from other cyclic aliphatic compounds.

2nd Group: Planar structure and conjugation: It contains comparative questions about aliphatic and planar structural compounds and 6 multiple choice questions related to condensed cyclic aromatic compounds emphasizing conjugation.

3rd Group: Huckel's Rule: It contains 4 multiple choice questions about heteroatom containing aromatic compounds and aromatic ions.

4th Group: It contains 8 multiple choice questions related to differences of aromatic compounds' reactions from aliphatic compounds' reactions.

All of the questions, except 3rd Group questions, prepared for aromaticity concept and properties were compiled from the books about University Selection Examination (Ö.S.S) and University Selection and Placement Examination (Ö.S.Y.S). In this case, other questions, except those in the 3rd group, are at the level of University Selection and Placement Examination.

Analysis of Data

Data were interpreted with SPSS Pocket Program by using average, t-test and variance analysis (one-way) techniques. Significance level was taken as 0.05. The groups' achievement scores and achievement classes in the test prepared for aromaticity concept and properties were presented in the Table 1.

FINDINGS

Findings have been given regarding the questions to be answered related to main purpose of the research.

The first question to be answered in the research was "Is there a statistical significance between the achievement level of the first and third grade students attending to Department of Chemistry in Faculty of Sciences and Arts, Faculty of Education in Dicle University and eleventh (last) grade secondary students related to applied achievement test in terms of ; a) the characteristic of aromatic compounds having cycle, b) planar structure and conjugation, c) Huckel's Rule and d) the reactions of aromatic compounds ?". This question has been examined in terms of students' achievement relating to have cyclic characteristic of aromatic compounds and findings have been presented in Table 2.

Aromatic compounds having cyclic property.

When Table 2 was reviewed, it was seen that the achievement score average changed between 2.21 and 5.17 with respect to level of the students. When the differences between averages were reviewed, university last grade students' achievement scores related to aromatic compounds having cycle were higher (X=5.14) and it was lowest scores about secondary school last grade students (X=2.21). The average of achievement scores of all students was 4.13.

Variance analysis (one-way) was used to determine whether the difference between average scores were statistically significant or not. Accomplished statistical analyses were presented in Table 3.

Statistical significance differences between groups have been determined at 0.05 level by making variance analysis. "Scheffe" test was used to determine which groups have the difference between. It has been understood that significant differences between university third grade students with university first grade and secondary third grade students were valid from the results of Scheffe test.

Table 1. The groups' achievement scores and achievement classes in the test

Groups	Maximum Score *	Achievement Limit Score**
1st Group: Aromatic compound has cycle	7	3.50
2nd Group: Planar structure and conjugation	6	3.00
3rd Group: Huckel's Rule	4	2.00
4th Group: Reactions of Aromatic Compounds	8	4.00

* The maximum score getting from every sub-group of the test is the sum of the number of questions in a group. The value of each correct answer has been accepted as '1' point. ** Achievement Limit Scores have been determined accepting half of maximum score as passing score.

Table 2. The Students' achievement average scores and standard deviation with respect to aromatic compounds having cyclic property

Groups	N	Average	ss
University 1st Grade	26	3.57	1.92
University 3rd Grade	113	5.14	1.93
Secondary School 3rd Grade	65	2.21	1.61
Total	204	4.13	2.16

Table 3. Variance Analysis with respect to aromatic compounds having cycle property

Source of Variance	SD	Sum of Squares	Average of Squares
Between Groups	2,00	272.69	136.34
Intra Groups	201	677,46	3.34
Total	203	950.15	

Secondary students' achievements were lowest and university third grade students' achievements were highest with respect to average scores. This result has showed that secondary students comprehended cyclic characteristic of aromatic compounds less but, university third grade students comprehended this concept more than other two groups. The students' achievements related to cyclic characteristic of aromatic compounds were evaluated with a total of 7 multiple choice questions. Accordingly, the maximum score to get from sub dimension of this test was 7. Third grade university students' achievements were high with respect to approach that was accepting half of maximum score as passing score. First grade university students' average scores were a little above the achievement level. Third grade university students' high level of achievements was an expected situation because, aromaticity concept and properties of aromatic compounds have been taught as a subject in Organic Chemistry Lesson.

There might be various reasons for first grade university students' achievement scores were in the limit of passing score. One of the reasons might be to get some main knowledge about aromaticity concept and properties by the students during University Selection and Placement Examination (Ö.S.Y.S) preparation stage.

One of the reasons that third grade secondary students' achievement scores were under the limit of passing score might be taking part of this subject in a less amount in instruction program. It has been also seen that samples of secondary schools' chemistry text books had this subject in a very little amount.

First question of the research was examined in terms of the students' achievements with respect to aromatic compounds' planar structure and conjugation properties and the findings were presented in Table 4.

Table 4. The Students' achievement average scores and standard deviation with respect to aromatic compounds' planar structure and conjugation properties

Groups	N	Average	ss
University 1st Grade	26	1.92	1.41
University 3rd Grade	114	2.58	1.54
Secondary 3rd Grade	65	1.55	1.23
Total	204	2.32	1.55

When Table 4 was reviewed, it was seen that the achievement score average related to planar structure and conjugated double bond containing properties was changed between 1.55 and 2.58 with respect to level of the students. When the differences between averages were reviewed, university last grade students' achievement scores were higher (% 2.58) and it was lowest scores for secondary school last grade students (X=1.55). The average of achievement scores of all students was 2.32.

Variance analysis (one-way) was used to determine whether the difference between average scores were statistically significant or not. Accomplished statistical analyses have been presented in Table 5.

Statistical significance differences between groups have been determined at 0.05 level by making variance analysis. "Scheffe" test was used to determine which groups have the difference between. It has been understood that significant differences between university third grade students with university first grade and secondary third grade students were valid from the results of Scheffe test. In other words, university third grade students have formed statistical significance difference. Secondary students' achievements were lowest and university third grade students' achievements were highest with respect to average scores. This result has showed that secondary students comprehended planar structure and having conjugated double bond characteristic of aromatic compounds less but, university third grade students comprehended this concept more than other two groups.

Accordingly, the maximum score to get from sub dimension of this test was 6 and achievement limit was 3. Findings from Table 4 showed that all of the groups' average achievement scores were under the limit of achievement. The students' achievements related to aromaticity concept and its properties were evaluated with a total of 6 multiple choice questions.

The first question of the research was examined in terms of the students' achievements with respect to aromatic compounds' Huckel's Rule property and the findings were presented in Table 6.

When Table 5 was reviewed, it was seen that the achievement score average related to Huckel's Rule property was changed between 0.96 and 2.26 with respect to level of the students. When the differences between averages were reviewed, university last grade students' achievement scores were highest (X= 2.26) and it was lowest scores for secondary school last grade students (X=0.96). The average of achievement scores of all students was 1.70.

Variance analysis (one-way) was used to determine whether the difference between average scores was statistically significant or not. Accomplished statistical analysis were presented in Table 7.

Statistical significance differences between groups have been determined at 0.05 level by making variance analysis. "Scheffe" test was used to determine which groups have the difference between.

Table 5. Variance Analysis with respect to Aromatic compounds' planar structure and having conjugated double bond property

Source of Variance	SD	Sum of Squares	Average of Squares
Between Groups	2,00	75.44	37.72
Intra Groups	202	417.66	2.06
Total	204	493.10	

F=18.24 Fp=0.000 p<0.05

Table 6. The Students' achievement average scores and standard deviation with respect to aromatic compounds' Huckel's Rule property

Groups	N	Average	ss
University 1st Grade	26	1.07	0.70
University 3rd Grade	114	2.26	1.25
Secondary 3rd Grade	65	0.96	0.76
Total	204	1.70	1.70

Table 7. Variance Analysis with respect to obeying Huckel's Rule property

Source of Variance	SD	Sum of Squares	Average of Squares
Between Groups	2,00	80.95	40.47
Intra Groups	202	229.88	1.13
Total	204	310.84	

It has been seen that significant differences between university third grade students with university first grade and secondary third grade students were valid from the results of Scheffe test. Secondary students' achievements were lowest and university third grade students' achievements were highest with respect to average scores.

The students' achievements related to the level of understanding Huckel's Rule were evaluated with 4 multiple choice questions. Accordingly, the maximum score to get from this sub dimension of this test was 4 and achievement limit was 2. Third grade university students' average scores were above the achievement limit according to the results in Table 6. University first grade and secondary students' average scores were quite below the achievement level. It can be said that university first grade and secondary students have comprehended aromatic compounds' Huckel's Rule lower than university third grade students. It has been seen that this property of aromatic concept has not been given in the secondary and first grade university instruction program but it was given in the third grade university instruction program. So, third grade university students' high level of achievements was an expected situation. Finally, first question of the research was examined in terms of the students' achievements with respect to aromatic compounds' reactions and the findings were presented in Table 8.

When Table 7 was considered, it was seen that the achievement score average related to aromatic compounds' reactions changed between 1.69 and 4.11 with respect to level of the students.

When Table 8 was reviewed, university last grade students' achievement scores were highest (X= 4.11) and it was lowest scores for secondary school last grade students (X=1.69). The average of achievement scores of all students was 3.10.

Variance analysis (one-way) was used to determine whether the difference between average scores were statistically significant or not. Accomplished statistical analysis was presented in Table 9.

Statistical significance differences between groups have been determined at 0.05 level by making variance analysis. "Scheffe" test was used to determine which groups have the difference between. It has been seen that significant differences between university third grade students with university first grade and secondary third grade students were valid from the results of

Scheffe test. In the other words, university third grade students have formed statistical significance difference. Secondary students' achievements were lowest and university third grade students' achievements were highest with respect to average scores. The students' achievements related to aromatic compounds' reactions were evaluated total 8 multiple choice questions. Accordingly, the maximum score to get from sub dimension of this test was 8 and achievement limit was 4.

Table 8. The Students' achievement average scores and standard deviation with respect to aromatic compounds' Reactions

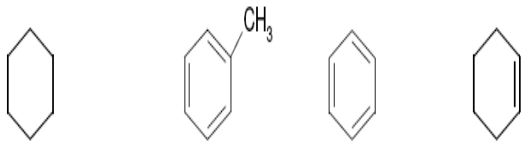
Groups	N	Average	ss
University 1st Grade	26	2.19	2.05
University 3rd Grade	114	4.11	2.12
Secondary 3rd Grade	65	1.69	1.04
Total	204	3.10	2.16

Table 9. Variance Analysis with respect to Aromatic Compounds' Reactions

Source of Variance	SD	Sum of Squares	Average of Squares
Between Groups	2,00	267.44	133.72
Intra Groups	202	685.40	3.39
Total	204	952.84	

The results of questions asked to the students in terms of determining characteristic properties of aromaticity can be summarized as follows:

The following questions were asked based on "Aromatic compounds should have at least one cycle";



Which of the compounds above is aromatic?

a) II and III b) II, III and IV c) only III d) III and IV

One of the striking points in this question was accepting every cyclic compound as aromatic compound making a mark for "c" choice by 10 secondary students of 65 ones. The same question was asked to first grade university students and 66 students of 100 had no answer because of having no information about the subject. Six students have accepted every cyclic compound as aromatic compound. This number was 4 of 114 third grade university students. The second question supporting the first question was asked to determine how the students perceived aromatic compounds for the same purpose.

What is the aromatic compound?

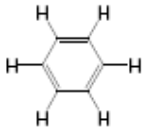
a) having a nice smell compound
b) Cyclic compound ,
c) Planar and cyclic compound having one double and one single bond by order.
d) Cyclic compounds having only one double bond would be aromatic.

When the results were reviewed, since 27 secondary students of 65 ones have made a mark for "b" or "e" choice, these 27 students have believed cyclic property for maintaining aromaticity. 16 students have accepted the compounds with nice smell as aromatic compounds. 74 university first grade students of 100 had no answer because of having no information about the subject and ten students have accepted every cyclic compound as aromatic compound. One student has accepted the compounds with nice smell as aromatic compounds. 6 third grade students of 114 had no idea about this topic, 16 students have accepted every cyclic compound as aromatic compound and eight of them accepted the every compound with nice smell as aromatic compound.

Geometric shape is planar because of sp^2 hybridization in aromatic compounds and they all have cyclic planar structure. It was asked that how many atoms placed in the same plane for the purpose of in what extent the students recognized planar geometry. Answers;

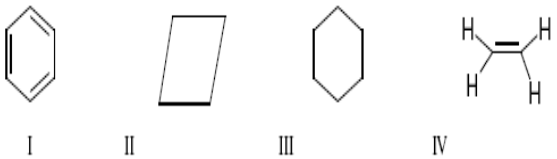
a) 6 H b) 6 C c) 6 C and 6 H d) 1 C and 1 H e) 2 C and 2 H

were like this. 28 secondary students of 65 ones have given correct answer and 70 first grade students of 100 students have stated that they had no idea but 12 of them have answered this question correct. 60 third grade students of 114 students have answered correct and seven students have not answered the question.



A question and answer choices about planar structure are as the follows.

Which one of the following represents planar geometry?

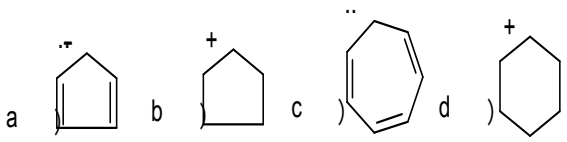


a) I and IV b) II and III c) only I d) only II e) only IV

The purpose in this question was to search the answer whether students know only benzene in planar geometry or students suppose every cyclic compound in planar geometry. Besides this, this question was asked to investigate whether students recognize planar geometry in both cyclic and linear chain structure or not. Only 8 of 65 secondary students could have correct answer. 17 of them have made a mark on choice "b", 18 students "c", 4 students "d", 17 students "e" and two of them had no answer. 76 of 100 first grade students had no answer and only five of them could have correct answer. 9 of them have made mark on choice "b", 8 students "c" and 2 students "e". Only 37 of 114 third grade students could have correct answer, 11 of them have made mark on choice "b", 30 students "c", 6 students "d" and 14 students "e". 16 students had no idea about the answer.

A question about Huckel's Rule is like this:

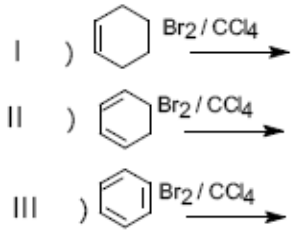
Which one of the following ions is aromatic?



e)Aromatic ion does not exist

It has been investigated the students' information about Huckel's Rule was indirect (Huckel's Rule was not included in secondary instruction program) and as it was expected, 36 secondary and 10 first grade students have been advocated that aromatic ion could not be existed. These two different groups of students could not have correct answer. 62 third grade students could have correct answer but 76 first grade students had no answer about this question.

Aromatic hydrocarbons' addition reactions occur in very slow rate than alkenes and aromatic compounds have no addition reactions. They give substitution reactions in special conditions. The following question was asked for this difference. What can you say about the rates of these three reactions?



a) III is the fastest b) III is the slowest c) I is the fastest d) I and III are the fastest e) I and III are the slowest.

8 of 65 secondary students, 6 of 100 first grade students and 44 of 114 third grade students could have correct answer for this question.

It has been given some information about benzene cycle in a similar question and asked which one was wrong.

Which one of the following information is wrong about benzene molecule?

a) It contains 3 Π bonds.
b) It contains 12 σ bonds.
c) It has planar structure.
d) It gives substitution reactions with halogens.
e) It gives addition reactions with halogens.

6 of 65 secondary students, 6 of 100 first grade students and 34 of 117 third grade students could have correct answer for this question.

One of the interesting results was that 10 of 60 university third grade students having correct answer about planarity above question have advocated unplanar structure of benzene. 10 students have had no answer, 21 students have stated that benzene could not give substitution reactions and 32 students had no information about benzene molecule containing 12 σ bonds. Only 34 students could have correct answer for this question.

CONCLUSION and DISCUSSION

It has been seen that the Aromaticity concept was given in a less amount in secondary school chemistry instruction program or even insufficient and misconceived form in some chemistry books by reviewing the last grade of secondary school chemistry text books. So, It can be stated that the secondary school instruction program should be reviewed and given place to aromaticity concept on a large scale. Besides this, concept maps can be used to develop aromaticity concept. For this reason, concept networks should be used.

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