Education Sciences
ISSN: 1308 7274 (NWSAES)
ID: 2019.14.1.1C0687

Status : Original Study
Received: September 2018
Accepted: January 2019

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DOI	http://dx.doi.org/10.12739/NWSA.2019.14.1.1C0687		
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IMPLEMENTATION OF CASE-BASED LEARNING (CBL) METHOD IN ANALYTICAL CHEMISTRY LABORATORY COURSE

ABSTRACT

In this research, the effect of case-based laboratory practices of Analytical Chemistry Laboratory course on 'Acid-Bases Titrations' topic on the academic achievement of students was examined. This study was conducted with the 2^{nd} year students (N=78) of the Science Teaching Program of a university in Izmir in the fall semester of 2014-2015 academic year. The study was pre-test and post-test control group research design. The results showed that there was a significant difference between the post-test academic achievement scores in favor of the experimental group. The results of the structured interview form also showed that the majority of the students had positive opinions concerning the case study and the material.

Keywords: Acid-Bases Titrations, Analytical Chemistry Laboratory, Case-Based Laboratory Practices, Science Teaching Students, Structured Interview

1. INTRODUCTION

Chemistry that is based on laboratory practices plays an important role in increasing the quality of life by contributing to different fields such as health, medicine, agriculture, food, energy and the environment. The place of chemistry that is contributing too many areas of science in education and training is inevitable. Laboratory practices are important in the development of scientific process skills such as observation, discussion, data collection that cannot be developed only with theoretical courses in chemistry education (Alkan, 2016; Figueiredo, Esteves, Neves and Vicente, 2016). On the other hand, the students could have difficulty in practicing their gained theoretical knowledge in the laboratory environment (Nakhleh, 1994). In this context, active learning methods are included in the laboratory environment to enable students to know how to easily convert their theoretical knowledge into practice (Flynn and Biggs, 2012; Kala, Yaman and Ayas, 2013; Rand et al., 2016; Sandi-Urena, Cooper, Gatlin and Bhattacharyya, 2011; Stephenson and Sadler-McKnight, 2016; Windle, McCormick, Dandrea and Wharrad, 2011).

Case-based learning method (CBL) from active learning methods based on problem-based learning (PBL) approach; is a learner-centered method that is applied to learners by giving a case study related to daily life. In this method, the teacher is in the position of the instructor and guide, and in the process learners acquire self-learning, logical reasoning, problem solving and decision making skills while working in a cooperative group on a problem connected

How To Cite:
Günter, T., Kılınç Alpat, S., and Özbayrak Azman, Ö., (2018). **Implementation of Case-Based Learning (Cbl) Method in Analytical Chemistry Laboratory Course, Education Sciences (NWSAES)**, 14(1):17-34, DOI: 10.12739/NWSA.2019.14.1.1C0687.

with daily life (Flynn and Klein, 2001; Lei, Guo, Chen, Qui, Gong and He, 2016). There are many studies in the literature that effectively use PBL and CBL in the fields of health, pharmacy, pharmacology, chemistry and engineering (Bridle et al., 2016; Crippen et al., 2016; Harman et al., 2015; Jansson, Söderström, Andersson and Nording, 2015; Marks and Eilks, 2010; Overton and Randles, 2015; Reddy, 2000; Schwartz-Bloom and Halpin, 2003; Taylor, Olofson and Novak, 2017). It seems that the PBL approach, the CBL method and the problems associated with daily life are effectively used to increase students' understanding and learning in the literature.

Especially, experiments on the topic of 'Acid-Bases Titrations' are mostly carried out in secondary school and undergraduate level in General Chemistry and Analytical Chemistry Laboratories and it has been determined that students have alternative concepts in this topic (Artdej, Ratanaroutai, Coll and Thongpanchang, 2010; Hoe and Subramaniam, 2016; Sheppard, 2006). When the relevant article is examined, it is also seen that there is a limited number of studies using CBL method based on PBL approach and daily-life scenarios of 'acid-bases and titrations' topic in the laboratory practices and theoretical courses. Karpudewan, Roth, and Sinniah (2016) examined the influence of students on the understanding and judgment of acid-bases concepts of green chemistry-based experiments in secondary chemistry lessons. Learning-centered approaches were used in experiments to produce environmentally friendly substances. The result of the study shows that using the learning-centered approaches in green chemistry-based laboratory studies enhances students' understanding and judgment of 'Acids and Bases' topic.

Nyachwaya (2016) examined the conceptualization of the students' understanding of acid-bases topic and the fluency in the use of scientific language in general chemistry at secondary level. In the study, a scenario-based on measuring the electrical conductivity of sodium hydroxide and diluted hydrochloric acid solution titration was developed and students worked on the scenario in groups. The result was that students were lacking in conceptual understandings and fluency in the use of scientific language and the majority of students did not associate conductivity with acid-bases neutralization topics. Dori and Sasson (2008) examined the effects of case-based computer-aided chemistry laboratory applications on the chemical understandings of secondary school students and their graphical drawing skills. The study was carried out by developing case studies based on drawing and interpretation of temperature, pH, conductivity and related graphs. It was achieved that this method increased students' chemical understandings and graph drawing skills in the study.

Reigosa and Jimenez-Aleixandre (2007) examined the performances of students on the process of problem-solving activities in the secondary physics and chemistry laboratory. The students developed experiments on the problems by developing problems such as separation of substances, volume measurement, acid titration, spring motion and measurement of spring mass. The results of the study showed that students took responsibility for their own learning and improved their performance. Miri, David, and Uri (2007) examined the effect of instructional strategies in developing upper-cognitive thinking skills on the students' critical thinking skills in science education at secondary level. The study showed that the students of the experimental group had higher critical thinking skills than the control groups and that the use of real-life related problems in the courses, the provision of an open-ended classroom discussion environment and the development of inquiry-based experiments improved the students' critical thinking skills. Hofstein, Shore, and Kipnis (2004) investigated the effect of inquiry-based laboratory practices in secondary chemistry classes on student achievement. It was aimed to provide realistic learning environments that enable students to organize information about chemical cases in the study. Topics such as acid-bases, stoichiometry, oxidation-reduction, bond, energy, chemical equilibrium, reaction rate in the chemistry laboratory course included in the study. It was achieved that the application developed students' inquiry-based learning capabilities in the chemistry laboratory.

2. RESEARCH SIGNIFICANCE

As seen in the literature review, there are a limited number of studies that use CBL and problems related to daily life in the undergraduate level Analytical Chemistry Laboratory courses and its effect on students' achievement concerning the relevant topic. In this context, because of the limited number of studies, it is considered that students' learning and understanding of the theoretical knowledge about acid-bases titrations topic in an undergraduate level laboratory environment can be achieved by using CBL-based laboratory applications. Therefore, this study is necessary for examining the effect of CBL-based laboratory applications on students' achievement about the relevant topic in undergraduate level Analytical Chemistry Laboratory and in the light of findings obtained in this research can fill the gap in the field of science education for further studies. The aim of this study is to examine the effect of case-based laboratory practices on Analytical Chemistry Laboratory course 'Acid-Bases Titrations' topic to the academic achievements of students studying in Science Teaching Program. The problem question of the study is: "What is the effect of case-based laboratory practices in Analytical Chemistry Laboratory course 'Acid-Bases Titrations' topic to the academic achievement of the second year students who study at the Science Teaching Program of a university in Izmir?". The sub-problem question is: "What are the opinions of the students who study the course with case-based laboratory practices about the case-study and the teaching material?"

3. EXPERIMENTAL METHOD-PROCESS

This research was pre-test and post-test control group quasi-experimental design.

3.1. The Study Group

The study group of the research constitutes second grade students (N=78) who study at two different branches of Science Teaching Program in one class of a university in Izmir. The students of two different branches in one class had similar achievement scores in the mid-term and final exams of Analytical Chemistry course in previous years. Therefore, one of the existing branches was randomly selected as control (n=40) and the other was selected as experimental group (n=38). This study group selection was made according to random sample selection technique which is not based on probability (Arlı and Nazik, 2010; Buyukozturk, Cakmak and Akgun, 2012). Implementation was carried out during six course hours in fall semester of 2014-2015 academic year. During this period, the students of the experimental group studied with the case-based laboratory practices, while the control group students conducted the course with the laboratory practices appropriate to the teaching plan. All students were informed before the application about that the implementation process and that they would not be exposed to any harmful chemical substances in the laboratory environment. In addition, informed consent forms were taken from students indicating that they volunteered to the study. The application was carried out by the same educational directors in both groups at the same time (6 course hours) (Cohen, Manion and Morrison, 2011; Taber, 2012).

3.2. Data Collection Tools

In this study, Acid- Base Titrations Achievement Test (ABTAT) and the structured interview form were used as data collection tools.

- **Acid-Base Titrations Achievement Test (ABTAT):**'Acid-Bases Titrations Achievement Test (ABTAT)', which consists of 16 open-ended questions concerning the topic of acid-bases titrations, was developed by taking three analytical chemistry and pedagogical expert opinions and using the related textbooks (Gunduz, 2008; Skoog, Holler and West, 1996) (See App.1). ABTAT test was prepared as including acid-bases titrations, based on the following sub-topics of acid-bases titration types, appropriate indicator selection, primer and secondary standard material, adjusted solution, titration curves and pH calculations, and reliability of the obtained data. Bloom's Taxonomy was used to design these sub-topics which should align with the open-ended questions asked. These questions consisted of knowledge, comprehension, application and analysis cognitive domains in accordance with Bloom's Taxonomy (Kotluk and Yayla, 2016; Tanık and Saracoglu, 2011). The 1^{st}, 6^{th}, 9^{th} and 11^{th}questions were prepared at the knowledge; the 2^{nd}, 3^{rd}, 7^{th}, 8^{th}, 10^{th}, 13^{th}, 14^{th} and 15^{th}questions were prepared at the comprehension; the 4^{th} and 5^{th} questions were prepared at the application and 12^{th} and 16^{th} questions were also prepared at the analysis cognitive domains. In addition, these open-ended questions in the ABTAT test were the questions which were asked in the mid-term and final exams of Analytical Chemistry and Analytical Chemistry Laboratory courses to the students studying at the departments of Chemistry Teaching and Science Teaching Programs in a university in Izmir in previous years. Test was applied as a pilot test to third, fourth, fifth grade students studying at the departments of Chemistry and Science Teaching Programs (N=99) who were taught the relevant topic in their previous years. In the analysis of open-ended questions in ABTAT test, they were categorized into clear understanding (CU), partial understanding (PU), misunderstanding (MU), incomprehension (IC) and unanswered (UA) categories and scored (Abraham, Grzybowski, Renner and Marek, 1992; Nakiboglu, 2001). The explanations, scores and some examples about the relevant topic of these categories were shown in Table 1.

Table 1. Explanations, scores and some examples

Categories	Explanations	Scores	Some examples
Clear Understanding (CU)	Exactly correct responses	3	'The active ingredient is acetic acid of the vinegar.'
Partial Understanding (PU)	Responses containing some correct aspects	2	The students can express the acid ratio of grape and apple vinegar partially: 'The acid ratio of the grape vinegar is higher than that of the apple vinegar.'
Misunderstanding (MU)	Responses containing incorrect information and partial understanding with special misconception	1	'Active ingredient of vinegar is acetaldehyde.'
Incomprehension (IC)	Responses with unrelated to the questions	0	The students have response the question of the acid ratio of apple and grape vinegar that the active ingredient of vinegar is acetic acid.
Unanswered (UA)	Empty responses	0	……………………(Blank)

The discriminatory and difficulty indices of the ABTAT test items were analyzed by the ITEMAN analysis program according to the responses given by the students. As a result of the item analysis, it was calculated that the mean item difficulty index (p) of the test was 0.564 and the mean discriminatory index (r) was 0.530. In addition, the reliability of the ABTAT test was determined using the SPSS package program and the reliability coefficient of the test (Cohen's Alpha) was found to be 0.704. In the light of these data, it was concluded that the reliability of ABTAT test was high and it had medium difficulty and good discrimination power. The ABTAT test was carried out without any items being removed by taking the opinions of three chemistry educators who were experts in the field. Therefore, it was determined that sufficient level of validity and reliability of the ABTAT test was provided. The test was applied to both experimental and control group as pre-test and post-test.

- **Structured Interview Form:** The structured interview form consisting of 7 open-ended questions prepared with three analytical chemistry and pedagogical expert opinions was applied to randomly selected (n=28) students from the experimental group at the end of the application (See App.2). The purpose of the form was to determine the opinions of the experimental group students about the developed case study and the teaching material.

3.3. Data Analyzing Method

The open-ended questions were again analyzed by the content analysis according to the categories given in Table 1. The obtained data were scored separately by three analytical chemistry and pedagogical experts and Pearson's correlation coefficient (r) was calculated as 0.970. The Pearson correlation coefficient is higher than 0.80 showed a high correlation between scores obtained by three researchers (Cohen, Cohen, West and Aiken, 2003; Fisher, 1915). Qualitative data obtained from the experimental and control groups using the ABTAT test was performed using appropriate statistical analyses through the SPSS package program. It was examined whether the data show a normal distribution in order to be able to select appropriate statistical analyses. Shapiro Wilk test was applied to investigate the normal distribution suitability of the data (Kartal, Kayacan and Selvi, 2013). Shapiro Wilk test result was $p<0.05$, so that it was decided that the distribution was not normal. Mann Whitney U and Wilcoxon tests were used from the non-parametric tests because the data were not fit to normal distribution. Mann Whitney U test was used for the comparison of independent variables between two groups, while Wilcoxon test was used for the comparison of change of dependent variables among groups. For all statistical comparisons with a p-value below 0.05 assumed as statistically significant. The content analysis of the structured interview form conducted by the experimental group at the end of the study was independently performed by three analytical chemistry and pedagogical experts. Code and themes were created from the obtained data. The agreement percentage for the encoder reliability was calculated with the $P=\frac{N_a \times 100}{N_a+N_d}$ (P=Agreement Percentage, N_a=Agreement Amount, N_d=Disagreement Amount) formula and found to be 0.84 (Bakeman and Gottman, 1997; Croll, 1986).

3.4. Creation of Case-Study and Teaching Material

For the study, a case-study related to the daily life titled *'Vinegar, what did you do to me?'* was prepared by taking three analytical chemistry and pedagogical expert opinions (See App.3). The case-study on acid-bases balance and titrations is based on the idea that a university student who wants to weaken and get rid of acne on her face is using apple and grape vinegar extensively. The case was organized to be associated with the sub-topics identified in the ABTAT test. The teaching material also contains a section titled *'Do you know these?'* in order to gain information about the daily use of the vinegar and the skin pH of the students.

3.5. The Application of Laboratory Practices

Both the experimental and control group students didn't do titration experiment before the application process. At the beginning of the laboratory course, the experimental group students were informed about the CBL method and the application process. Then, ABTAT pre-test was applied to both groups (1 course hour). The similarities, differences and course hours of the laboratory practices for both groups were given in Table 2. After ABTAT post-test, a structured interview form was implemented to identify the experimental group students' opinions on case-study and teaching material. During the experimental process, both groups performed the same experiment concerning the weak acid-strong base titration by using the same apparatus in the laboratory environment. The experimental group reached the solution and the experimental design under the guidance of the case-study and the educational director, whereas the control group students were given the relevant experiment. The experiment conducted by both groups is as follows. Firstly, the students prepared the adjusted sodium hydroxide solution (NaOH) for the titration experiment. 1 gram of NaOH is weighed into a 100mL beaker and is dissolved in 75mL of distilled water. The solution is added with 0.025 gram of barium chloride ($BaCl_2$). After waiting for a while, the solution is filtrated in order to remove turbidity. The filtrate is taken up in a 250mL volumetric flask and the solution is made up to 250mL with v/v distilled water. Oxalic acid ($H_2C_2O_4$) is used as the primer standard substance and approximately 0.1 gram of $H_2C_2O_4$ (the value of weight should be recorded exactly) is weighed. 30 mL of distilled water is added to an Erlenmeyer flask and the weighed $H_2C_2O_4$ is dissolved by transferring into this Erlenmeyer flask. After the substance is completely dissolved, 2 drops of phenolphthalein (FF) indicator are added. The prepared NaOH solution is filled into the burette and the titration process is continued until a permanent color change (pink color) is observed. The amount of NaOH solution spent is read carefully. The normality of NaOH solution (N_{NaOH}) is calculated by using the following formula:

$$N_{NaOH} \times V_{NaOH} = \text{gram } H_2C_2O_4 \Big/ \left(E_a/_{1000}\right) \quad (E_a = \text{Equivalent weight})$$

Therefore, the adjusted NaOH solution for the titration experiment is prepared. Secondly, the students weighed approximately 100 grams of apple vinegar sample (T). They transferred the weighed sample to a 1000 mL volumetric flask and completed it with 1000 mL of distilled water. Then, they took 25mL (V_n) of this solution and it was added to Erlenmeyer flask. They added 2 drops of FF indicator. The sample was titrated with the solution of NaOH until the end point and the consumption volume was recorded exactly (V_{NaOH}). Then, the students calculated the amount of acetic acid (CH_3COOH) (%HAc) in the apple vinegar sample by using the formula and wrote the relevant reaction (weak acid-strong base) as follows:

$$\%HAc = N_{NaOH} \times V_{NaOH} \times E_a \times \left(\frac{V_t}{V_n}\right) \times \left(\frac{100}{T}\right)$$

$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$$

The students did the same experimental process and also calculated the amount of acetic acid in the grape sample.

Table 2. The similarities and differences of the application of CBL-based laboratory practices and laboratory practices appropriate to the teaching plan

CBL-based laboratory practices	Laboratory practices appropriate to the teaching plan	Course Hours
After ABTAT pre-test application, the students were given a case-study and asked to comment on the case-study. After students' comments on the case-study were taken, the students were divided into groups (3 groups of six people; 4 groups of five people) (Discussion-Brainstorming)	After pre-test application, the students were given the weak acid-strong base titration experiment prepared in accordance with the teaching plan. The students were divided into groups (5 groups of six people; 2 groups of five people).	15 minutes
Seven sub-research topics were given to groups, one sub-topic for each group. The students were asked to study their research topics in groups until the next laboratory course. Sub-research topics given to the students are as follows: • Acidic or basic properties and active ingredients of products such as food, cleaning, and cosmetics used in daily life (Group I), • The benefits and harms of vinegar (Group II), • Acid-bases titration types, selection of appropriate indicator and primer substance (Group III), • The definitions of acid, base, pH, primer standard substance and secondary standard substance, adjusted solution, indicator (Group IV), • Titrimetry species and basic principles, how to form titration curves of strong bases with different strength acids and pH calculations (Group V), • Statistical analysis concepts and tests for determining the reliability of data (Group VI), • Quantitative analysis applications of acid-bases titrations, calculation of the amount of the substance and analysis of the active substance in the vinegar (Group VII) (Research-Collaborative Work).	The students were asked to come up to the next laboratory course by studying the same sub-topics mentioned in the experimental group under the guidance of given experiment (Research-Collaborative Work)	15 minutes
The students presented the research topics they had searched in groups and discussed the topics with inter-group question-answer context and in cooperation with an educational director. After the narration of the research topics, the case-study was given again to the students during the application process (Presentation-Discussion-Interpretation-Collaborative Work).	The students had a verbal exam about the same sub-research topics and the given experiment in the laboratory environment. The verbal exam is their typical procedure for the students in the laboratory environment before conducting the related experiment.	1 hour+ 30 minutes
Students formed an experimental design for weak acid-strong base titration according to the case-study by the guidance of discussion environment and educational director. They performed this experiment in groups in laboratory environment (Discussion-Brainstorming- Reaching a Solution-Designing the experiment for the weak acid-strong base titration- Conducting the Experiment-Collaborative Work).	The students performed the given experiment in groups by the guidance of the educational director. (Conducting the experiment for the weak acid-strong base titration-Collaborative Work)	2 hours
At the end of the application, ABTAT was applied to the students as a post-test.	At the end of the application, the students were administered ABTAT as a post-test.	1 hour

4. FINDINGS AND DISCUSSIONS

3.6. Findings and Discussions on ABTAT Test Content Analysis

The results of the ABTAT pre-test and post-test content analysis conducted by the students in the experimental and control groups are given in Table 3 and Table 4, respectively:

Table 3. Frequency (f) and percentage (%) values according to the categories for the ABTAT pre-test of the experimental and control group students

Experimental Group (N=38)										
Categories	CU		PU		MU		IC		UA	
Questions	f	%	f	%	f	%	f	%	f	%
1	8	21.05	19	50.00	6	15.79	3	7.90	2	5.26
2	2	5.26	28	73.69	5	13.16	1	2.63	2	5.26
3	3	7.90	14	36.84	1	2.63	14	36.84	6	15.79
4	-	0.00	11	28.95	-	0.00	21	55.26	6	15.79
5	-	0.00	11	28.95	1	2.63	11	28.95	15	39.47
6	2	5.26	12	31.58	13	34.21	5	13.16	6	15.79
7	4	10.53	20	52.63	12	31.58	1	2.63	1	2.63
8	-	0.00	30	78.95	6	15.79	1	2.63	1	2.63
9	5	13.16	24	63.15	-	0.00	5	13.16	4	10.53
10	-	0.00	22	57.89	13	34.21	-	0.00	3	7.90
11	5	13.16	7	18.42	2	5.26	10	26.32	14	36.84
12	-	0.00	9	23.68	6	15.79	20	52.63	3	7.90
13	-	0.00	6	15.79	10	26.32	17	44.73	5	13.16
14	-	0.00	2	5.26	4	10.53	23	60.53	9	23.68
15	1	2.63	8	21.05	6	15.79	8	21.05	15	39.48
16	-	0.00	1	2.63	13	34.21	10	26.32	14	36.84
Total	30	4.93	224	36.84	98	16.12	150	24.67	106	17.44
Control Group (N=40)										
Categories	CU		PU		MU		IC		UA	
Questions	f	%	f	%	f	%	f	%	f	%
1	7	17.50	22	55.00	7	17.50	2	5.00	2	5.00
2	-	0.00	32	80.00	7	17.50	1	2.50	-	0.00
3	3	7.50	19	47.50	2	5.00	12	30.00	4	10.00
4	-	0.00	19	47.50	-	0.00	12	30.00	9	22.50
5	-	0.00	10	25.00	-	0.00	13	32.50	17	42.50
6	1	2.50	17	42.50	11	27.50	4	10.00	7	17.50
7	1	2.50	15	37.50	17	42.50	6	15.00	1	2.50
8	-	0.00	25	62.50	11	27.50	2	5.00	2	5.00
9	-	0.00	31	77.50	2	5.00	4	10.00	3	7.50
10	1	2.50	14	35.00	20	50.00	2	5.00	3	7.50
11	-	0.00	7	17.50	2	5.00	12	30.00	19	47.50
12	-	0.00	4	10.00	4	10.00	23	57.50	9	22.50
13	-	0.00	3	7.50	3	7.50	25	62.50	9	22.50
14	-	0.00	-	0.00	-	0.00	34	85.00	6	15.00
15	-	0.00	4	10.00	6	15.00	11	27.50	19	47.50
16	-	0.00	3	7.50	12	30.00	4	10.00	21	52.50
Total	13	2.03	225	35.16	104	16.25	167	26.09	131	20.47

Table 4. Frequency (f) and percentage (%) values according to the categories for the ABTAT post-test of the experimental and control group students

Experimental Group (N=38)										
Categories	CU		PU		MU		IC		UA	
Questions	f	%	f	%	f	%	f	%	f	%
1	29	76.32	2	5.26	5	13.16	-	0.00	2	5.26
2	4	10.53	25	65.78	5	13.16	4	10.53	-	0.00
3	5	13.16	25	65.78	4	10.53	4	10.53	-	0.00
4	6	15.79	19	50.00	-	0.00	11	28.95	2	5.26
5	5	13.16	25	65.79	2	5.26	2	5.26	4	10.53
6	14	36.85	9	23.68	13	34.21	2	5.26	-	0.00
7	5	13.16	19	50.00	12	31.58	1	2.63	1	2.63
8	3	7.90	26	68.42	6	15.79	2	5.26	1	2.63
9	4	10.53	27	71.04	3	7.90	1	2.63	3	7.90
10	8	21.05	13	34.21	15	39.48	-	0.00	2	5.26
11	11	28.95	13	34.21	2	5.26	3	7.90	9	23.68
12	1	2.63	14	36.85	7	18.41	13	34.21	3	7.90
13	4	10.53	15	39.47	4	10.53	10	26.31	5	13.16
14	-	0.00	3	7.90	6	15.79	17	44.73	12	31.58
15	12	31.58	14	36.85	2	5.26	1	2.63	9	23.68
16	6	15.79	2	5.26	14	36.85	6	15.79	10	26.31
Total	117	19.24	251	41.28	100	16.45	77	12.67	63	10.36
Control Group (N=40)										
Categories	CU		PU		MU		IC		UA	
Questions	f	%	f	%	f	%	f	%	f	%
1	16	40.00	5	12.50	10	25.00	-	0.00	9	22.50
2	-	0.00	24	60.00	11	27.50	2	5.00	3	7.50
3	4	10.00	27	67.50	4	10.00	2	5.00	3	7.50
4	2	5.00	19	47.50	2	5.00	10	25.00	7	17.50
5	1	2.50	22	55.00	3	7.50	4	10.00	10	25.00
6	2	5.00	18	45.00	11	27.50	5	12.50	4	10.00
7	-	0.00	20	50.00	16	40.00	3	7.50	1	2.50
8	-	0.00	23	57.50	15	37.50	2	5.00	-	0.00
9	-	0.00	25	62.50	11	27.50	1	2.50	3	7.50
10	4	10.00	7	17.50	27	67.50	2	5.00	-	0.00
11	5	12.50	8	20.00	2	5.00	10	25.00	15	37.50
12	-	0.00	7	17.50	3	7.50	25	62.50	5	12.50
13	-	0.00	10	25.00	2	5.00	25	62.50	3	7.50
14	-	0.00	7	17.50	3	7.50	23	57.50	7	17.50
15	8	20.00	8	20.00	6	15.00	5	12.50	13	32.50
16	1	2.50	2	5.00	13	32.50	11	27.50	13	32.50
Total	43	6.72	232	36.25	139	21.72	130	20.31	96	15.00

It is seen that the percentage of the responses given by the students in both groups in CU category after the application increased and this increase is higher in the experimental group (4.93%-19.24%) than the control group students (2.03%-6.72%) when the percentages of the responses given by the students in the experimental and control groups to the ABTAT pre- and post-test were examined according to the categories. It was determined that the percentage of respondents in the PU increased, the percentage of respondents in the IC and UA categories decreased in both groups. When the frequency percentages in the MU category were compared, the experimental group students had an increase of 0.33% in the ABTAT post-test (MU, 16.45%) compared to the ABTAT pre-test (MU, 16.12%); control group students had an increase of 5.47% in the same category in the ABTAT post-test (MU, 21.72%) compared to the ABTAT pre-test (MU, 16.25%). The increase in the percentages of respondents in both the CU and PU categories in the post-test of students in both groups could be interpreted as the better understanding of the students as a result of the implementation process.

It is seen that the frequency percentage in the CU category of the acetic acid (CH_3COOH) of the active ingredient in the 1st question and the percentage of the frequency in the PU category in both groups between 2-5 and 7-9 questions are both high when the ABTAT post-test content analysis of the students of the experimental and control groups was examined. It was observed that the students of both groups were able to give some examples to the acids and bases in materials such as food, cosmetics, cleaning products used in daily life and that there was a lack of clarity of the titration of acetic acid and the formula required for the calculation and the statistical determination of the reliability of the results of the analysis of the amount of active substance in the 2-5 questions. Both groups identified acid-bases, strong/weak acid-bases, but they did not give some examples, interpreted the pH value incompletely, and partially identified acid-base titration in determining the amount of acid or base contained in a substance in the 7-9 questions.

In addition, according to the content analysis results of the ABTAT post-test, it was determined that the frequency percentages in the different categories of the students in the experimental and control groups were high in the 6th and 11-16 questions. It was seen that the experimental group had a higher frequency of response in the CU category and the control group had a higher response in the PU category for the 6th question. The majority of the experimental group had a full understanding of the fact that the active ingredient of the vinegar is acetic acid and that the acid ratio of the grape vinegar is 5-10% higher than that of the apple vinegar. The majority of the control group expressed in the category of PU that the active ingredient of vinegar is acetic acid. The control group students were found to have deficiencies in comparing the acidity of grape vinegar and apple vinegar. It was determined that the students in the experimental group had a high response frequency in the PU category and the control group students could not understand or answer the same questions in the 11-13 questions and 15th question. This finding shows that the study group partially understands the acid-bases titration types, the conditions for selecting the primer standard substance and indicator in a titration, how the titrant can be adjusted in the titration, and how weak acid-strong base titration can be done. In question 14, incomprehension was seen in both experimental and control groups. In the 16th question, it is seen that both groups have higher frequency of responses in the MU category.

In the same question, it is also seen that the control group students' frequency of responses in the MU category is equal to their frequency of responses in the UA category. This finding showed that both groups could not understand that a small amount of barium chloride ($BaCl_2$) had to be added into the glass container due to the presence of impurities and because of the presence of impurities in the preparation of the sodium hydroxide (NaOH) solution and that they made a mistake in the pH calculations for titration curve formation in weak acid-strong base titration. In addition, the responses in the MU category in the ABTAT post-test of both groups were examined according to same categories and some examples of misunderstandings in the relevant categories of the students are given in Table 5.

Table 5. Some examples of misunderstandings of the experimental and control groups

Misunderstandings	Some examples of students' expressions
Active ingredient of Vinegar	"Active ingredient of Vinegar is $H_2C_2O_4$ (Oxalic acid)" (EG-S32) "Active ingredient is base." (EG-S8) "NaOH is used for active ingredient of Vinegar." (CG-S2) "Active ingredient of Vinegar is acetaldehyde." (CG-S3) "Active ingredient of Vinegar is H^+ ion." (CG-S13) "Active ingredient of Vinegar is nitric acid." (CG-S18) "The active ingredient of Vinegar may be OH^-." (CG-S20)
Cleaning agents - Food	"Soap is an acidic substance." (EG-S8) "All cleaning materials are in basic group." (EG-S10) "The cleaning agents used contain many acids such as NaOH, HCl." (EG-S28) "Bleach is an example of acids." (CG-S13) "Bleach is acid, muriatic acid is strong base." (CG-S40) "Food such as lemon, orange, vinegar may be basic." (CG-S35) "Water is basic featured." (CG-S39)
Analysis of acetic acid	"Qualitative analysis methods are used for the analysis of acetic acid." (CG-S23)
Reliability of analysis results	"In terms of the reliability of the analysis results, they may have benefited from G test that is a statistical test used for rough measurements. "(EG-S38)
Difference of the amount of active ingredient between the apple and grape vinegar	"Grape vinegar is a stronger acid than apple vinegar." (EG-S27) "The amount of NaOH may be different." (CG-S2) "Because apple and grape are different fruits, the active ingredient in them is different. For this reason, the ingredients of vinegars consist of them are also different." (CG-S26) "The amount of acetic acid in apple vinegar is higher." (CG-S38) "I think it is. The active ingredient used in the grape vinegar is a stronger base. It may not be the strongest base used in the apple vinegar." (CG-S39) "I do not think there's a difference." (CG-S40)
Acid-Base and Strong/Weak Acid-Base	"The pH value is far from 7, the stronger the acid or base becomes." (EG-S30) "Looking at the pH value, we know that it is a strong or weak acid. The stronger acid is near pH 1, the weaker acid is near 7. Likewise, the closer to pH 14 is the stronger base, the closer to pH 7 is the weaker base." (EG-S25) "We can determine whether the acid or base is strong or weak by looking at the pH value. Sample pH value = 1-2 strong acid. pH = 13-14 strong base." (CG-S38) "It is strong acid if it gives H^+ ion in water and strong base if it gives OH^- ion in water." (CG-S40)
pH value	"The pH value helps me to understand whether it is strong or weak acid." (EG-S13) "pH is used for acidity and basicity strength value." (EG-S36) "The pH is a molar concentration of a $[H^+]$ or $[OH^-]$ ion of a substance." (CG-S10) "An acidic, basic or strong-weak interpretation of a known pH-value substance can be made." (CG-S31)
Analytical method used to find acid-base amount	"Can be analyzed by redox reactions." (EG-S14) "With precipitation, complexation, reduction-oxidation reactions." (CG-S27)
Primary standard substance	"Substances that's concentration is unknown are put in the burette." (EG-S14) "It is a substance that's concentration is unknown." (EG-S18) "It is called for change at the end point." (CG-S32) "That is the substance to be obtained in titration." (CG-S40)

Table 5. Some examples of misunderstandings of the experimental and control groups (continuation)

Misunderstandings	Some examples of students' expressions
Indicator	"It is the substance that helps dissolve the substances (acid or base). Used as an adjuvant in the reaction." (EG-S13) "It is a substance that increases the activity of the acid or base used in a solution." (CG-S39) "It is the substance that accelerates the reaction." (CG-S40)
Equivalence point	"The moment we see full color." (EG-S4) "The value of the two substances starting to react during titration." (EG-S15) "Meeting of acid and base at a certain point and getting to alkaling of an acidic analyte." (CG-S1) "The equivalency is the division or point from the point where the color change occurs after the titration." (CG-S4) "The equivalence point is when the substances entering the reaction are of equal volume." (CG-S18) "The equivalence point is the average value of the acidity or basicity of the substance." (CG-S20) "It is the point at which the analyte changes color." (CG-S38) "The equivalence point is the pH of the acid or base is exactly 7." (CG-S40)
End point	"The equivalence point is equal to the end point."(EG-S34) "The equivalence point is equal to the end point." (CG-S18) "The end point is equal to the equivalence point. It is the moment when the titration process is completed. In this case, the solution in conical flask is pink." (CG-S5) "It is the point where the acid solution is now basic or the basic solution is now acidic." (CG-S37) "It is the point that the analyte is saturated to the substance that's concentration is known." (CG-S40)
Titration	"Analytical procedure for finding out whether a substance is acid or base." (CG-S8) "Identification of the characteristics of the substances." (CG-S30)
Acid-base titration types	"Base design with a controlled acid solution; Acid design with a controlled base solution." (EG-S11) "Redox reactions, reduction-oxidation reactions." (CG-S25)
The determination conditions of the primary standard substance and indicator	"The primary standard substance was the substance whose concentration was unknown. We know the substance contained in the burette that concentrations are known is acidic or basic. We determine the substance of which concentration is unknown (primary standard substance) according to its acidity or basicity. If the indicator is an acid or a base, the acid should be determined accordingly, and the base should be determined according to the indicator." (EG-S18) "For example, if HCl is analyzed, phenol phthalate is used, if a base is analyzed, methyl orange is used." (CG-S40)
Preparation of adjusted solution	"In titration, the substance in the burette is called the titrant, while the substance in the reagent is called the analyte. The solutions used as titrant in the titration must be adjusted. A NaOH solution of known concentration is diluted with water to make the adjusted solution and used as a titrant in titration." (EG-S10) "The solutions used as titrant in the titration must be adjusted. We will use some amount of material in gr or mL, then we can concentrate with water to get the solids in the desired molar." (CG-S1)
Preparation of NaOH solution (Titrant solution)	"The NaOH solution should be prepared quickly, as it is volatile. Water should be added slowly." (EG-S11) "When preparing NaOH, white smoke and sodium flotation should be taken into consideration and prepared carefully." (CG-S4)

Table 5. Some examples of misunderstandings of the experimental and control groups (continuation)

Misunderstandings	Some examples of students' expressions
Weak acid-strong base titration	"HCl and NaOH can be used for titration with a weak acid strong base." (CG-S1) "Examples are KCl and NaOH. They can be titrated using phenol phthalate." (CG-S6) "NaOH and HCl titration." (CG-S40)
Solution environment and pH values calculation at beginning, before equivalence, at equivalence point and after equivalence in weak acid-strong base titration	"The environment is acidic before equivalence, neutral at equivalence and acidic after equivalence." (CG-S7) "It is basic before equivalence, acidic at equivalence point and after equivalence." (CG-S12) "It is neutral at equivalence point." (CG-S15) "pH is 7 (neutral) at equivalence point." (CG-S31) "Environment is neutral at equivalence point and pH is equal to 7. Before equivalence $pH > 7$; after equivalence $pH < 7$." (CG-S34) "Since acid and base amounts are equal to each other, acid-base is equal at equivalence point. pH=7." (CG-S40)

It was observed that there are misunderstandings in the calculation of acetic acid analysis, reliability of analysis results, difference in amount of active substances in apple and grape vinegars, definition of acid-base and strong-weak acid base solutions, pH value, analytical methods used in determining the amount of acid-base, primary standard substance, indicator, equivalence point, end point and titration definitions, acid-bases titration types, conditions of determination of the primary standard substance and the indicator, preparation of the adjusted solution and NaOH titrant solution, weak acid strong base titration and equimolarity, equivalence and equivalence solution medium and pH values categories both in the ABTAT post-test of the experimental and the control groups as shown in Table 5. It was determined that the students had misunderstandings in the topics of acid-base titration, strength of an acid or base, equivalence point, end point, indicator, definition of primary standard substance and pH calculations when the literature was examined (Artdej, Ratanaroutai, Coll and Thongpanchang, 2010; Bayrak and Bayram, 2011; Cetingul and Geban, 2011; Hoe and Subramaniam, 2016; Kala, Yaman and Ayas, 2013; Mutlu and Sesen, 2016; Pınarbası, 2007; Sheppard, 2006). In this study, in addition to the literature, it was observed that students had misunderstandings about the method used to determine the amount of acid-base in a substance, the definition of the titration concept, the selection of the appropriate primary standard substance and indicator and how to prepare the adjusted solution.

3.7. Findings and Discussions on Mann Whitney U Test Analysis of ABTAT Test

The Mann Whitney U test results of the ABTAT pre- and post-test academic achievement scores of the students in the experimental and control groups and Wilcoxon test results of ABTAT pre- and post-test scores intra-groups are as shown in Table 6-8.

Table 6. Comparison of ABTAT pre- and post-test academic achievement scores of students between experimental and control groups

	Groups	N	$\bar{x} \pm s$	Median	Min-Max	U	p
Pre-test	Experimental	38	16.7±5.38	17	0-25	576.00	0.065
	Control	40	14.9±3.77	16	3-20		
Post-test	Experimental	38	25.26±6.52	26	7-40	241.00	<0.001
	Control	40	18.4±4.43	18.5	7-25		

Table 7. Comparison of changes between ABTAT pre- and post-test results for the experimental and control groups

Groups		N	$\bar{x} \pm s$	Median	Min-Max	z	p
Experimental	Pre-test	38	16.7±5.38	17	0-25	-4.898	<0.001
	Post-test	38	25.26±6.52	26	7-40		
Control	Pre-test	40	14.9±3.77	16	3-20	-3.382	0.001
	Post-test	40	18.4±4.43	18.5	7-25		

Table 8. Comparison of percentage change (%) of ABTAT test results between experimental and control groups after laboratory practices

Groups	N	Median	Min - Max	U	p
Experimental	37	0.55	-0.24 - 2.18	538.00	0.039
Control	40	0.24	-0.63 - 4.00		

As seen in Table 6, the Mann Whitney U test results showed that there was no significant difference between ABTAT pre-test academic achievement scores of students in experimental and control groups (U=576.00, $p>0.05$); however, ABTAT post-test academic achievement scores of the students in each groups showed a significant difference in favor of experimental group (U=241.00, $p<0.05$). The Wilcoxon test results in Table 7 showed that the changes between ABTAT pre- and post-test results for the experimental and control group were found to be statistically significant (z=-4.898, $p<0.001$; z=-3.382, p=0.001, respectively). Although this result shows that there was not a significant difference between case-based laboratory practices and laboratory practices appropriate to the teaching plan, the increase in the scores of the experimental group students in the ABTAT post-test was higher (0.55) than the increase in the scores of the control group students (0.24) in the ABTAT post-test. According to these findings, it can be said that case-based learning practices applied in Analytical Chemistry Laboratory increased academic achievement. There are studies about 'Acid-Bases Titrations' topic on undergraduate level Analytical Chemistry Laboratory course in which PBL-based CBL method and the problems connected with daily life improve the learners' perceptions, performances, motivations, supra-cognitive skills and positive attitudes in the literature discussed below. Cam and Geban (2017) examined the impact of CBL method on the motivation and attitudes of science teacher candidates towards chemistry lessons in the university science level. In the study, it was determined that the soil properties of the various regions are acidic, basic and neutral, and that soil activity can be changed by adding some chemical substances. In addition, eight case studies based on real life examples in the form of pH enhancement in plant growth, acidity of the stomach, calcification of the tea kettle, acid rain and tooth decay were developed and implemented. The results of the study are that CBL method can help students improve their motivation towards chemistry lessons and develop positive attitudes. Ramstedt et.al. (2016) examined the impact of inquiry-based approach, case studies and PBL in university level environment and analytical chemistry course on students' motivation and being active learners. In addition, online groups, group discussion environments, laboratory work and quizzes were used in the study to support students in the inquiry-based learning process. The study included sampling, organic and inorganic matter analysis, surface analysis. It was achieved that the majority of students had positive opinions on implementation and that the practice supported their learning. Cancela et.al. (2016) performed similar activities in real life situations in the chemistry engineering laboratory course. Experiments based on real-life problems such as calorimetry, biodiesel production from oil, production of soap, calculation of concentration of an acid solution, production of perfume, metal coating, production of crystals in different forms, analysis of aspirin and coke, use of energy in chemical processes were included in the study. The results of the study showed that the students worked in cooperative groups and were pleased that they were doing their experiments self-managed. Rand et.al. (2016) conducted a neutralization experiment for acid rain in the teaching of the introduction to general chemistry laboratory course and they recorded video on this topic. In the study, students firstly measured the conductivities of different water samples, then measured the conductivity of the resulting solution by passing the sulphuric acid solution through a column containing calcium carbonate. The students tried to learn how the neutralization reaction between acid rain and limestone was realized and formed the conductivity-volume graph with this application. In the study, an animation based video about the experimental setup was developed and used. The result of the study showed that students were more willing to learn chemistry concepts related to daily life than conventional teaching and that videos showing laboratory techniques improved the students' performance in the laboratory environment and that they prepared the students better in the new experiments.

Temel (2014) aimed to determine the tendency of teacher candidates to think critically about 'Acids and Bases' and the perceptions of problem-solving ability and the effect of PBL on the tendencies and perceptions. A scenario consisting of five sessions included sub-topics such as corrosive substances, acids/bases, pH concept, corrosive properties of acids and bases, based on the theme of a child mistakenly ingesting a corrosive substance was developed and implemented in the study. The research reached the conclusion that PBL improved students' critical thinking tendencies and problem solving abilities. Yoon et.al. (2014) examined the impact of PBL on the students' creative thinking, self-regulation, and self-assessment skills in analytical chemistry laboratories. In the research, three scenarios were developed and applied for the analytical chemistry laboratory course. The first scenario is based on acid-bases titrations and gravimetry dependent on the treatment of wastewater contaminated with acid and bases solutions; the second scenario is sedimentation and EDTA titrations based on the definition of metal and non-metal ions; the third scenario is to learn analytical methods of ultraviolet-visible region and infrared spectroscopy based on the development of laboratory teaching materials. The results of the study showed that PBL enhances students' creative thinking and self-regulation skills and develops self-assessment skills for problem solving and group work. Kelly and Finlayson (2007) examined the impact of PBL-based laboratory practices on practical and transferable skills, content knowledge, and scientific understandings of students in university-level chemistry classes. Scenarios were developed and implemented in order to learn the concepts of mole, molarity, acid-bases, indicator, gas and titration methods in the study. The conclusion of the study showed that PBL-based laboratory practices enabled students to work in active and collaborative groups in the laboratory environment, and that discursive environments and practical activities enhanced meaningful learning for students.

3.8. Findings and Results on the Content Analysis of Structured Interview Form

A content analysis of the structured interview form was conducted to obtain the opinions of the students of the experimental group (n=28) about the case-study and the teaching material at the end of the application. The content analysis of the positive and negative opinions of students about the name, quality and memorability of the case-study is given in Table 9.

Table 9. Positive and negative opinions about the case-study

Positive Opinions			Negative Opinions		
Main Theme 1: The name of case-study	f	%	Main Theme 1: The name of case-study	f	%
Sub-themes:	30	81.08	Sub-themes:	7	18.92
Interesting Appropriate Nice	17 12 1	56.67 40.00 3.33	Not very interesting	7	100.0
Main Theme 2: Quality of the case-study	f	%	Main Theme 2: Quality of the case-study	f	%
Sub-themes:	52	94.55	Sub-themes:	3	5.45
Related to daily life Interesting Memorable	28 23 1	53.85 44.23 1.92	Not very interesting	3	100.0
Main Theme 3: Memorability	f	%	Main Theme 3: Memorability	f	%
Sub-themes:	40	100.0	Sub-themes:	None	
Harms of excessive use of vinegar (Irritation of the face, damage to the skin)	19	47.50	None		
Grape vinegar is stronger acid than apple vinegar	5	12.50			
Titration	4	10.00			
The vinegar is weak acid	3	7.50			
The pH range should be known	2	5.00			
The causative agent of the vinegar	2	5.00			
Acetic acid detection of the vinegar	2	5.00			
Dilution of the vinegar is necessary	1	2.50			
Definition of acid	1	2.50			
Experiment materials and experiment	1	2.50			
Total (Positive Opinions)	122	92.42	Total (Negative Opinions)	10	7.58

The majority of students expressed positive opinions that the case-study was interesting and appropriate, related to daily life and memorable, and that the memorable parts of the case-study were about the harms of excess vinegar usage and the stronger acidity of the grape vinegar than the apple vinegar as shown in Table 9. Only ten students had a negative opinion that the-case study and its name were not interesting. The content analysis of the positive and negative opinions of the students on the usage purpose, the orientation of the topic, the wakefulness, the advantages and disadvantages of the developed material, and the difficulties on understanding of the topic were shown in Table 10.

Table 10. Positive and negative opinions about the teaching material

Positive Opinions			Negative Opinions		
Main Theme 4: Usage purpose of the material	f	%	Main Theme 4: Usage purpose of the material	f	%
Sub-themes:	14	100.0	Sub-themes:	None	
Appropriate	11	78.57	None		
Comprehensive and instructive	2	14.29			
Intriguing	1	7.14			
Main Theme 5: The advantages of material	f	%	Main Theme 5: The disadvantages of material	f	%
Sub-themes:	43	89.58	Sub-themes:	5	10.42
New knowledge acquisition	22	51.16	Insufficient title	1	20.00
Totally advantageous	5	11.63	Time-consuming	1	20.00
Related to daily life	5	11.63	A little bit more detail should be given	1	20.00
Memorable	3	6.98	Understandably must be more	1	20.00
Intriguing	3	6.98	Being too long	1	20.00
Nice	1	2.33			
Strengthening old information	1	2.33			
Make effective observation	1	2.33			
Appropriate	1	2.33			
Comprehensive and instructive	1	2.33			
Main Theme 6: Direction of material to the topic, difficulty in understanding	f	%	Main Theme 6: Direction of material to the topic, difficulty in understanding	f	%
Sub-themes:	49	81.67	Sub-themes:	11	18.33
Director	22	44.90	Statistical calculations (Errors)	3	27.27
New knowledge acquisition	12	24.49	Titration curves	2	18.18
No forced parts	9	18.37	Time-consuming	1	9.09
Memorable	2	4.08	More emphasis on the subject	1	9.09
Related to daily life	2	4.08	Titration	1	9.09
Comprehensive and instructive	1	2.04	Primary standard substance	1	9.09
Elimination of deficiencies	1	2.04	Questions of equivalence point	1	9.09
			EP-BP separation	1	9.09
Main Theme 7: Building an idea of how to make acetic acid detection in the vinegar	f	%	Main Theme 7: Building an idea of how to make acetic acid detection in the vinegar	f	%
Sub-themes:	38	97.44	Sub-themes:	1	2.56
Creating an idea	21	55.26	Unnecessary	1	100.0
Titration idea	10	26.32			
Learning with materials	6	15.79			
Interesting/ Intriguing	1	2.63			
Total (Positive Opinions)	144	89.44	Total (Negative Opinions)	17	10.56

The majority of students expressed opinions that the purpose of the material was appropriate, comprehensive, instructive, intriguing, that the material was completely advantageous and that it was an opportunity, a guide and an idea for new information as shown in Table 10. Only seventeen students had negative opinions that the material was too time-consuming and long to hold and that the material had difficulty in understanding statistical calculations and titration curves.

In the literature, these findings are supported by some studies. For instance, Koo et al. (2016) found that students were satisfied with the processing of the course with video and case studies, and their knowledge gains, performance and learning perceptions were increased. However, the students had negative opinion that the practice was time-consuming. Ekici's study (2016) showed that teacher candidates have positive opinions that PBL is interesting, lead to study collaborative, lead to exchange ideas, developed problem-solving skills, enabled better and quicker learning, improved knowledge access and creative thinking skills, and allowed identification of problems related to daily life. In the study, it was stated that the prospective teachers had difficulty in connecting to daily life in PBL, difficulty in identifying the problem, reluctance, presence of crowded classes, time-consuming and not attractive.

4. CONCLUSION AND RECOMMENDATIONS

The study results showed that there was a significant difference in the ABTAT post-test academic achievement scores favoring the experimental group students ($U=241.00$, $p<0.05$) according to Mann Whitney U test. The Wilcoxon test results showed that there was a significant difference between the ABTAT pre- and post-test scores intra-groups ($z=-4.898$, $p<0.001$ for the experimental group; $z=-3.382$, $p=0.001$ for the control group). In addition, it was found that the percentage change of ABTAT test results between the experimental and control group students were higher in the experimental group (0.55) than the control group (0.24). ABTAT post-test content analysis results showed that case-based learning method increased the students' clear and partial understandings. These findings are supported by some studies in the literature (Cam and Geban, 2017; Cancela, et al., 2016; Kelly and Finlayson, 2007; Ramstedt, et. al., 2016; Rand, et. al., 2016; Temel, 2014; Yoon, et. al., 2014). According to the results of the ABTAT post-test content analysis, it was determined that the experimental and control group students had some misunderstandings stated below. These expressions are based on students' misconceptions about acid-base titration types, the definition of concepts such as acid or base strength, equivalence point, end point, indicator and primary standard substance, and pH calculations.

This finding is also supported by some studies in the literature (Artdej, Ratanaroutai, Coll and Thongpanchang, 2010; Bayrak and Bayram, 2011; Cetingul and Geban, 2011; Hoe and Subramaniam, 2016; Kala, Yaman and Ayas, 2013; Mutlu and Sesen, 2016; Pınarbası, 2007; Sheppard, 2006). In addition, it was for the first time that the students had misconceptions about choosing the method to be used in determining the amount of acid-base in a substance, the definition of the titration concept, the determination of the primary standard substance and indicator suitable for titration, and the preparation of the adjusted solution in the study. It is thought that this issue can shed light on other studies to overcome the students' relevant misconceptions. At the end of the application, the results of the content analysis of the structured interview form with the students of the experimental group showed that the frequency of the positive opinions (f:266, 90.79%) of the students about the case-study and the teaching material was higher than the frequency of negative opinions (f:27, 9.21%). The majority of students have positive opinions that the name and nature of the case-study is interesting, appropriate, connected with daily life, and memorable; the material is appropriate, comprehensive and instructive for the usage purpose, provides new information, is entirely advantageous, is guiding the topic and is suggestive. Negative opinions include the fact that the case-study and the material are time-consuming and long held. These positive and negative opinions stated by the students are supported by some studies in the literature (Ekici, 2016; Koo et. al., 2016). As a result; it was achieved that case-based laboratory practices increased students' academic achievements, and majority of students had positive opinions on the case-study and the material in Analytical Chemistry Laboratory Course 'Acid-Bases Titrations' topic. These findings can fill the gap concerning the effect of CBL-based laboratory practices on the students' achievement about the relevant topic in science education literature and can shed the light on further studies. It is considered that the students' theoretical knowledge gained in the chemistry courses together with the case studies connected with daily life in the laboratory environment will be effective in increasing the academic achievements and contribute to other studies to be done in this topic. In addition, this case study can be applied again by increasing the duration of application process and by reducing the number of experimental group in future research.

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APPENDICES (EKLER)

Appendix 1. ABTAT Test

1. What could be the active agent of the vinegar?
2. Do you think that different foods such as fruits and vegetables, cleaning and cosmetic products we use in our daily lives are acidic or basic? Could you give them 10 examples?
3. What method can be used to analyze the active substance in vinegar, can you explain?
4. How can the amount of active substance in vinegar be calculated?
5. How can the reliability of analytical results for active substance amount be determined statistically?
6. Could there be a difference in the amount of active substance in apple and grape vinegar?
7. How can you explain the fact that a substance is acid or basic, whether the acid or base is strong or weak with giving examples?
8. What is the pH and how can you interpret the pH value of a solution?
9. What analytical methods can be used to determine the amount of acid or base in a substance?
10. Could you explain the concepts of titration, primary standard substance, equivalence point, end point and indicator?
11. What are acid-base titration types?
12. How are the primary standard substance and indicator chosen in a titration?
13. Should the solutions used as titrant in the titration adjusted? How is the adjusted solution prepared?
14. What should be considered when preparing the NaOH solution?
15. How can a weak acid be titrated with a strong base? Can you explain by giving an example?
16. What are the solution environments of a titration at initial, equivalent as titrant added, at equivalence point and after equivalence? How can the environments pH values be calculated for each condition?

Appendix 2. Structured Interview Form

1. Is the name of the case-study interesting and appropriate?
2. Is the case-study interesting and related to daily life?
3. What's left in your mind from case-study?
4. Is the material suitable for the usage purpose?

5. What are your positive and negative opinions about the material, considering the advantages and disadvantages of the material? Write down, please.
6. Could the material direct you to the acid-base topic? Were there any parts you had difficulty in understanding?
7. Did you get an idea of how you can determine acetic acid in the vinegar through the material?

Appendix 3. Case Study (*Vinegar, What Did You Do to Me!!!*)

VINEGAR, What Did You Do to Me!!!

Pelin's, who studies at the second undergraduate degree in Biochemistry Department of Aegean University, visa exams will start after one week. Pelin, who is very worried and stressed about the exams, also has difficulty in how she will work and focus. After having chatted with her classmates about the exams, Pelin gets stressed even more and she goes home to start study but she sees that there are guests when she gets home. Her mum's friends tell Pelin that she has gained weight and that her face is getting more acne. They recommend clearing the face with vinegar and drinking vinegar half an hour before breakfast in the morning. Pelin is very sorry for this situation. After a week, her exams will start anyway, she knows that she eats more than she is stressed, and that her face is no longer as smooth as before. Pelin starts to clean her face every day with grape vinegar, drinking a tea spoon grape vinegar half an hour before breakfast in the morning for a month based on this suggestion. At the same time, she is more careful not to consume carbohydrate-rich foods. She loses 5 kg in a month, but her face begins to peel and bubble. In this case, she stops applying vinegar to her face, but goes on a low carbohydrate diet and she drinks an apple vinegar instead of a tea spoon grape vinegar before breakfast in the morning. One day later, late at night Pelin is taken to the hospital with symptoms of stomach ache, vomiting, headache and respiratory distress. Pelin is found to have metabolic acidosis, low blood glucose and LDL, high levels of potassium, and urine pH lower than 7.35 as result of biochemical analyzes.

Pelin is urgently treated for electrolyte imbalance and dehydration, to remove bicarbonate deficiency and to raise blood sugar. In addition, the diagnosis of irritation of the skin and the appropriate treatment of balancing the pH of the skin should be applied. Dr. Engin asks Pelin if she has any previous illnesses or she use any medications. Pelin says that she entered a very strict diet, she used to drink a tea spoon grape vinegar before breakfast in the mornings, cleaned her face with vinegar, vinegar irritated her face, but continued to drink a tea spoon apple vinegar in the morning instead of the grape vinegar. Dr. Engin tells Pelin not to drink vinegar and to go to a doctor who specializes in skin. Pelin considers the doctor's suggestions and shares this incident with her friends. Her friends discuss why vinegar causes such a situation and they want to investigate and analyze the substance of the vinegar with help from the department instructors. They are told that they will be able to do the analysis of the grape and apple vinegar by working in the laboratory after the visa exams. Pleased with this situation, Pelin and her friends are eagerly waiting for the upcoming visa exams as well as their analysis.

DO YOU KNOW THESE?

1. What is your positive and negative thoughts about the name of the scenario, its connection with daily life, whether it is interesting or not?

2. What kind of analysis did Pelin and her friends think? What would you do to find the amount of active ingredient of vinegar?

3. The fat and sweat secreted by the skin determine the skin pH. With the effect of the ferments in the skin, this pH drops to 4. Due to the evaporation in the areas where sweat glands are present, the microorganisms may increase in the presence of basicity of the environment. Therefore, the skin must be disinfected. Can vinegar be used as an acidic preservative for this?