Eurasia Journal of Mathematics, Science & Technology Education, 2016, **12**(1), 57-86

A Comparison of Different Teaching Designs of 'Acids and Bases' Subject

Neslihan Ültay
Giresun University, TURKEY
Muammer Çalik
Karadeniz Technical University, TURKEY

•*Received 16 January 2015* •*Accepted 20 March 2015* •*Published online 12 Oct 2015*

Inability to link the acid-base concepts with daily life phenomena (as contexts) highlights the need for further research on the context-based acid-base chemistry. In this vein, the aim of this study is to investigate the effects of different teaching designs (REACT strategy, 5Es learning model and traditional (existing) instruction) relevant with 'acids and bases' subject on pre-service science teachers' conceptions and attitudes towards chemistry and to compare them with each other. Within quasi-experimental research design, the sample comprised of 95 pre-service science teachers from Faculty of Education in Giresun University, Turkey. Three intact groups were randomly assigned as either experimental and control groups. To gather data, Acid-Base Chemistry Concept Test (ABCCT), Chemistry Attitudes and Experiences Questionnaire (CAEQ) and semi-structured interviews were used. The results denote that REACT strategy is effective in helping the pre-service science teachers retain their gained conceptions in long-term memory whilst 5Es learning model is efficient in achieving conceptual learning. Finally, future studies should test the effects of REACT strategy and 5Es learning model on different variables (i.e. sample, subject, scientific process skills, scientific inquiry) over a longer period of time (i.e. one semester or one-year).

Keywords: acids and bases, REACT Strategy, 5Es learning model, contextual learning, constructivism

INTRODUCTION

Constructivist learning theory claims that learning is an interaction between new knowledge and pre-existing knowledge (e.g. Bybee, Taylor, Gardner, van Scotter, Powell, Westbrook & Landes, 2006; Driver, 1981). To achieve constructivist learning, 3Es (Explore-Explain-Elaborate) (called Learning Cycle Model), 4Es (Engage-Explore-Explain-Evaluate), 5Es (Engage-Explore-Explain-Elaborate-Evaluate) and 7Es (Excite-Explore-Explain-Expand-Extend-Exchange-Examine) learning models have been released (e.g. Bybee, 2003; Eisenkraft, 2003). Of these models, 5Es learning model, which has been adopted for structuring teaching and learning, is widely used by the science educators (Bybee et al., 2006). However, some authors point to shortcomings of elaboration stage (forth step in 5Es learning

Correspondence: Muammer Çalik,
Department of Primary Teacher Education, Fatih Faculty of Education, Karadeniz Technical University, 61335 Söğütlü, Trabzon, Turkey.
E-mail: muammer38@hotmail.com
doi: 10.12973/eurasia.2016.1422a

ISSN: 1305-8223

model) that asks the students/learners for linking their gained experiences with daily life or socio-scientific or science-technology-society issues (Kurnaz & Çalık, 2008). Unfortunately, most of 5Es learning papers have confused this stage with the last one (evaluation stage) (e.g. Er Nas, Coruhlu & Cepni, 2010). Inability to associate daily life or socioscientific issues with scientific knowledge (Demircioğlu, Demircioğlu & Çalık, 2009; Gilbert, 2006; Stolk, Bulte, de Jong, & Pilot, 2009a; Ültay & Çalık, 2012) calls for a new learning pedagogy, for example context-based approach, which centralize the learning and teaching around one main context. Because the context-based approach also deploys constructivist learning theory (e.g. Berns & Erickson, 2001; Crawford, 2001; Glynn & Koballa, 2005), the student's pre-existing knowledge initially has a pivotal role in knowledge-building; but the context-based approach exploits relevant contexts that activate student's pre-existing knowledge in learning new knowledge. Hence, the context-based approach creates a "need-to-know" basis to develop coherent mental maps of knowledge and to increase the relevance of the subject (e.g., Ültay & Çalık, 2012). Given these advantages, Bennett and Lubben (2006) report that the context-based courses have the potential to improve student engagement in chemistry learning, and help them to acquire a better understanding of their environment.

State of the literature

- A decrease in students' interests and attitudes towards chemistry drives chemistry educators to look for inquiry-based alternative ways (i.e., REACT strategy and 5Es learning model) to stimulate these issues.
- Inability to link the acid-base concepts with daily life phenomena (as contexts) highlights the need for further research on the context-based acid-base chemistry.
- Despite the fact that REACT strategy (as contextual based approach) stresses its motivational/attitudinal role, this has also yet been unexplored.

Contribution of this paper to the literature

- The main contribution of this paper to the literature relates to how different teaching designs influence pre-service science teachers' (PSTs') conceptions and attitudes towards chemistry.
- The present study sheds light on feasibility and insights of popular models/strategies (i.e. 5Es learning model and REACT strategy).
- The current study models how to adapt popular/contemporary learning approaches (REACT strategy and 5Es learning model) in pre-service education (especially, science education).

Since the context-based approach to science/chemistry teaching has become increasingly popular (e.g. Barker & Millar, 1999; Yager & Weld, 1999), a few context-based science curricula have been developed in many countries, for example Salters Advanced Chemistry in the UK (Barker & Millar, 2000; Bennett & Lubben, 2006), Chemistry in Context (Schwartz, 2006) and ChemCom (Sutman & Bruce, 1992) in the USA, Industrial Chemistry in Israel (Hofstein & Kesner, 2006), Chemie im Kontext in Germany (Parchmann et al., 2006), and the Chemistry in Practice in the Netherlands (Bulte, Westbroek, de Jong & Pilot, 2006) (see Ültay & Çalık, 2012, for further information). Thereby, these projects have intended to enable the students to conceive how science/chemistry is related to their daily lives (King, 2012) by actively taking their own learning responsibility (Stolk et al., 2009a, b). To accomplish the context-based approach, Relating-Experiencing-Applying-Cooperating-Transferring (REACT) strategy has been launched by going over teachers' views and their created sample materials (CORD, 1999). That is, REACT strategy is an output of teachers' observed experiences (CORD, 1999; Crawford, 2001; Souders, 1999) instead of that of theoretically designed issues (i.e., 5Es learning model, see Ültay & Çalık, 2011a). Given a decrease in students' interests and attitudes towards chemistry (Driel, 2005), science/chemistry educators should look for inquiry-based alternative ways (i.e., REACT strategy and 5Es learning model) to stimulate these issues.

Rationale of the study

Various researchers between 1989 and 2014 have contributed towards understanding of the key ideas about acids and bases (i.e. definitions of acids and bases, strengh of acids and bases, pH and pOH, and acid-base reactions) (see Appendix 1) and have highlighted needs for further studies.

The acid-base studies cover middle school (e.g., Bilgin & Yahşi, 2006; Botton, 1995; Oversby, 2000; Sisovic & Bojovic, 2000), secondary school (e.g., Cokelez & Dumon, 2009; Hand, 1989; Yaman, Demircioğlu & Ayas, 2006; Wilson, 1998), undergraduate (e.g., Bradley & Mosimege, 1998; Yıldız, Yıldırım & İlhan, 2006), pre-service education (e.g., Üce & Sarıçayır, 2002; Özmen, 2003), in-service education (e.g., Cho, 2002; Drechsler & Driel, 2008), and post-graduate education (e.g., Wilson, 1998). Further, of these sample groups, Grades 8 (e.g. Bilgin & Yahşi, 2006; Burhan, 2008; Özmen, Demircioğlu, Burhan, Naseriazari & Demircioğlu, 2012) and 10 (e.g. Ekmekçioğlu, 2007; Geban, Taşdelen & Kırbulut, 2006; Ouertatani, Dumon, Trabelsi, & Soudani, 2007; Tamer, 2006) and pre-service education have been the most popular due to several reasons. For example, in Turkey, the grade 8 students firstly introduce the acid-base concepts through science curriculum. Also, the grade 10 students encounter the acid-base chemistry at an advanced level. Further, the pre-service education (especially for science/chemistry student-teachers) purposes to get them to have subject matter and/or pedagogical content knowledge of the acid-base concepts that shape their future teaching careers as well as their students' conceptions of these concepts. In fact, it is obvious that the teachers that do not fully understand the content of science (i.e. acid-base chemistry) (as uncompleted conceptual understanding) may transmit their alternative conceptions to their students or cause new alternative conceptions (Çalık & Ayas, 2005; Kolomuç & Ayas, 2012; Quiles-Pardo & Solaz-Portole´s, 1995). For this reason, remedying pre-service science teachers' alternative conceptions of the acid-base chemistry would be worthwhile for their future teaching experiences (Çalık & Ayas, 2005). Hence, they may have an opportunity with acquiring related subject matter knowledge (Çalık & Aytar, 2013; Çalik et al., 2015; Pfundt & Duit, 2000) that is a pre-request for effective teaching (Garnett & Tobin, 1988). Given this opportunity in mind, a few studies (see Appendix 1) have focused on remedying and/or identifying pre-service and/or in-service teachers' alternative conceptions of the acids-bases subject (e.g. Cho, 2002; Üce & Sarıçayır, 2002; Wilson, 1998).

A great variety of data collection instruments has been employed in the acid-base studies. However, concept test as a cognitive measure (Bradley & Mosimege, 1998), interviews (Drechsler & Driel, 2008; Hand, 1989; Kala et al., 2013; Üce & Sarıçayır, 2002), and attitude or aptitude scales (i.e.Kılavuz, 2005; Üce & Sarıçayır, 2002) have been widely preferred to measure the sample's views/attitudes and their conceptual understanding of the acid-base concepts. Following these three data collection trends, we deployed them in this current study.

The experimental acid-base studies have reported that the treatment group with a new teaching design (i.e., cooperative learning, REACT strategy, 5Es learning model, conceptual change text, concept maps, computer-assisted instruction, and analogies) indicated better performance in conceptual understanding of the acid-base concepts than did the control one. Also, several of these studies emphasized that some alternative conceptions were still robust to change even after the instruction (Kala et al., 2013; Özmen, Demircioğlu, & Coll, 2009). For chemistry attitude studies, some found positive attitudinal change towards chemistry (Botton, 1995; Feng & Tuan, 2005) but others elicited no attitudinal change towards chemistry (Üce & Sarıçayır, 2002). This inconsistency needs still to be clarified. Furthermore, inability to link the acid-base concepts with daily life phenomena (as contexts) (e.g. Özmen, 2003; Bozkurt et al., 2005) highlights the need for further research on the context-based acid-base chemistry. Only one study by Demircioğlu et al. (2012), which is only limited to the neutralization concept in Grades 7-8, supports this need. Despite the fact that REACT strategy (as context-based approach) stresses its motivational/attitudinal role, this has also yet been unexplored. Similarly, all experimental acid-base studies, except for Demircioğlu et al. (2012), compared their experimental groups with control groups. However, none of the acid-base studies has compared 5Es learning model and REACT strategy (as popular models/strategies) with each other. Also, because the acid-base chemistry studies with 5Es learning model have conducted with Grade 10 (e.g. Kılavuz, 2005) and Grade 11 (e.g. Pabuccu, 2008) students, the current study proposes to model how to adapt popular/contemporary learning approaches in pre-service education (especially, science education). A Turkish idiom illustrates our position in this research: *'if everybody clears up his or her home front, there is no need to use a street sweeper'*! For example, Pinarbasi, Sozbilir, and Canpolat (2009), who determined chemistry student-teachers' misconceptions of colligative properties, suggested that a substantial review of teaching strategies at tertiary education is needed. Overall, we hypothesize that practical experiences with REACT strategy and 5Es learning model will be an important indicator in enhancing the pre-service science teachers' conceptions of the acid-base chemistry and positively changing their attitudes towards chemistry.

The aim of this study

The aim of this study is to investigate the effects of different teaching designs (REACT strategy, 5Es model and traditional (existing) instruction) relevant to 'acids and bases' subject on the pre-service science teachers' (PSTs') conceptions and their attitudes towards chemistry, and to compare them with each other. The following research questions, in turn, guide the current study:

1. Are there any statistically significant differences between the experimental (taught by REACT strategy and 5Es learning model) and the control groups' conceptions of 'acids and bases' subject?
2. Which of the teaching designs have the greatest effect on the PSTs' long-term memory (as retention of conceptual understanding) of 'acids and bases' subject?
3. Which of the teaching designs positively affect the PSTs' attitudes towards chemistry?

RESEARCH METHODOLOGY

Because the current study investigates the effects of independent variables (the teaching interventions--REACT, 5Es learning model and traditional/existing instruction) on dependent variables (student conceptions and attitudes towards chemistry), it follows a quasi-experimental research design (Creswell, 2003).

Sample

The sample of the study comprised of 95 PSTs (aged 17-20 years) drawn from three intact classes (as convenient sampling) from Department of Science Education, Giresun University, Turkey. Within a quasi-experimental research design (Creswell, 2003), the sample was devoted to two experimental (REACT strategy, n = 30, 18 females and 12 males; 5Es learning model, n = 32, 17 females and 15 males) and one control (n = 33, 16 females and 17 males) groups for existing/traditional teaching design. All PSTs were informed that their assessments would be used as data for a research project, but only if they agreed and signed the consent forms. Further, the authors emphasized assurances of confidentiality.

The PSTs are placed into the universities in regard to their orders of preference and their nation-wide scores administered by Assessment, Selection and Placement Center (Ölçme, Seçme ve Yerleştirme Merkezi—ÖSYM). That is, the sample under investigation listed Giresun University and science teacher education programme in their orders of preference (maximally 30 universities/programmes amongst 179 Turkish universities—69 of them have science teacher education programme-- and various programme options). A four-year science teacher education programme, which somewhat includes all discipline based science courses (i.e. chemistry, physics and biology), covers a total of 240 European Credit Transfer System (ECTS) (180 ECTS for compulsory courses and 60 ECTS for elective courses). All science teacher education programmes in Turkey have to follow the same syllabus of any compulsory course suggested by Higher Education Council. For example, because Year 1 does not contain any elective course, it includes only such compulsory courses as General Chemistry I-II, General Chemistry Laboratory I-II, General Physics I-II, General Physics Laboratory I-II. Of these courses, General Chemistry I-II cover topics such as gases, reactions in solution, atomic structure, electronic structure, periodic table, chemical bonds, theory of chemical bonding, oxidation-reduction reactions, chemical equilibrium, acids and bases, chemical equilibrium, chemical thermodynamics, chemical kinetics, electrochemistry and stoichiometry. In point of the 'acids-bases' subject, the PSTs are principally expected to learn 'definitions of acids and bases, strength of acids-bases, meanings and calculations of pH and pOH, and acid-base reactions'.

Data collection tools

Data was gathered by using, Acid-Base Chemistry Concept Test (ABCCT), Chemistry Attitudes and Experiences Questionnaire (CAEQ) (see Appendix 2), and semi-structured interviews. Because the current study attempted to overcome the PSTs' alternative conceptions, an in-depth literature review was used to shape statements/distacters and reasons in the ABCCT rather than adopting items/questions (see Table 1). The ABCCT contained two-tier items within three different parts. That is, the first part of the ABCCT comprised of multiple-choice tiers. The first tier necessitates to be circled whether the statement with alternative conception is true or false, and the second tier requests to indicate the reason for the first tier response (i.e. see sample item--Item A2). Likewise, the second part of the ABCCT consisted of a multiple-choice first tier and an open-ended second tier that calls the PSTs for indicating their reasons of the first tier response (i.e. see sample item--Item B4). Similar procedure was followed in the third part of the ABCCT (i.e. see sample item--Item C3). Table 1 shows the characteristics of the ABCCT items.

Table 1. Characteristics of the ABCCT items

Principal Concepts	Item	Number of Item
Definitions of Acids-bases (Theories of Arrhenius, Brønsted-Lowry and Lewis; Conjugate acid-base pairs, Autoprotolysis of water; Polyprotic acids; Ions pairs in polyprotic acids; Acidic, basic and amphoteric oxides)	A2, A3, A7, A10, A11, B1, B2, B6, B12, C1, C2, C8, C9, C11, C12	15
Strength of acids-bases (Strong and weak acids-bases; Relationship between the strength of chemical bond and acidicity/basicity; Strengths of oxoacids and organic acids)	A1, A2, A4, A8, A9, B3, B4, B5, B7, B10, C3, C4, C5, C8, C10	15
Meanings and Calculations of pH and pOH (Definitions of pH and pOH; Relationship between pH/pOH value(s) and strength of acid/base)	A1, A5, A9, B4, B7, B10, C4, C7	8
Acid-base reactions (Definition of hydrolysis; Hydrolysis of acids-bases; Neutralization)	A6, B8, B9, B11, C6	5

Three sample items are presented in the following:

A2. HCl and NH_3 are acids. But NH_3 is stronger acid than HCl.

a) True
b) False*
c) No idea

Please select your reason of choosing the option;

a) NH_3 has more hydrogen atoms.
b) The pOH value of NH_3 is greater.
c) NH_3 has hydrogen bonds.
d) NH_3, which includes hydrogen atoms, is a base.*

B4. Which of the solutions is a weak acid?

a) pH=1 b) pH=3 c) pH=7 d) pH=10 e) pH=12*

Please explain your reason of choosing the option; ……………

C3. The acid strength depends on the number of H atom, whilst the base strength relies on the number of OH molecule.

a) True b) False* c) No idea

Please explain your reason of choosing the option; ………………

CAEQ, with 69 items in three parts, was improved by Dalgety, Coll, and Jones (2003). Given the current study's context and specialized chemistry courses in the first-year of the study, only the first part of the original survey was adapted into Turkish setting. The original CAEQ used a 7-point Likert scale in the first part, included 21 items in 7 subgroups (chemists, chemistry research, science documentaries, chemistry web sites, chemistry jobs, talking to my friends about chemistry and science fiction movies). This survey was adapted into Turkish context by Ültay and Çalık (2011b). Confirmatory factor analysis with AMOS 18™ denoted three sub-groups in a total of 14 items; chemists (Items 1-6), chemistry research (Items 9-12) and chemistry jobs (Items 16-19) (see Ültay & Çalık, 2011b, for further information).

Semi-structured interviews were used for data triangulation. Interview protocol consisted of 20 principal questions. The first 14 interview questions, which were in harmony with the ABCCT, were asked to all interviewees. The last 6 interview questions probed REACT and 5Es groups' ideas and attitudes about the teaching intervention and were only directed to the experimental groups. The control group was excluded from the last 6 interview questions in that they were exposed to traditional/existing teaching design. Also, if necessary, the researchers asked follow-up questions to elaborate any idea depicted by the interviewee. Interviews were conducted with 18 volunteer PSTs (6 for each group) who applied for the authors' announcement of volunteer interviewee selection. Each interview session lasted 20-25 minutes and was tape-recorded. In brief, all data instruments, except for semi-structured interviews, were administered through pre-, post-, and delayed post-test design in fall semester of 2010-2011 academic year. That is, the ABCCT and CAEQ were administered as the pre-tests one week before the teaching intervention and immediately re-administered as the post-tests after the teaching intervention. Also, they were employed as the delayed-post-tests ten weeks after the teaching intervention. The semi-structured interviews were conducted after the teaching intervention.

Validity and reliability of data collection instruments

A group of experts (two chemistry educators and one science educator for the ABCCT; a chemistry educator, a science educator, and a language specialist for CAEQ; two chemistry educators for the semi-structured interview protocol) ensured the data collection instruments' face validity, readability, and content validity. Also, five student-teachers, who were not part of the PST sample under investigation, were used for a test study to determine validity and clarity. This test phase resulted in some minor revisions the instruments. Further, all instruments then underwent a comprehensive pilot-test with the PSTs (ABCCT, n = 91; CAEQ, n = 279; semi-structured interviews, n =6).The reliability coefficients (Cronbach alpha values) were found to be 0.78 for ABCCT and 0.82 for CAEQ, which are higher than the acceptable reliability coefficient (0.70) suggested by Hair, Black, Babin, Anderson, and Tatham (2006). Further, two chemistry educators separately categorized the PSTs' responses to the ABCCT. The inter-rater reliability co-efficient was found to be 74% and any disagreement was solved through negotiation. Overall, these values and procedures indicate that the instruments are able to reliably measure the PSTs' conceptions and their attitudes towards chemistry.

Data analysis

In analyzing responses to the ABCCT, the researchers adapted criteria recommended by Abraham, Gryzybowski, Renner, and Marek (1992). That is, the first-tier of each item was classified under *True* (2 points), *False* (one point) and *Blank* (zero point) whilst the second-tier of each item was labeled under *Sound Understanding (SU)* (3 points), *Partial Understanding (PU)* (2 points), *Partial Understanding with Specific Alternative Conception (PUSAC)* (1 point) and *Blank or No Understanding* (Zero point). Hence, because maximum score of each item was 5 points (as a combination of the first- and second tiers), the PSTs maximally took 175 points for the ABCCT. Further, in calculating effect of each teaching design on conceptual change, the PSTs' responses to the ABCCT were exposed to count on frequency of each alternative conception. Later on, the percentage is found in the following formulate: (frequency of each alternative conception/total counted responses)*100.

A 7-point Likert scale was used through a strongly negative response (1 point) and a strongly positive response (7 points) for each of 14 CAEQ items. After evaluating the PSTs' responses to the ABCCT and the CAEQ, their total scores for the pre-test (PrT), the post-test (PoT), and the delayed post-test (DT) were imported and statistically analyzed with SPSS13™. To measure the effects of independent variables (the teaching interventions--REACT, 5Es learning model and traditional/existing instruction) on dependent variables (student conceptions and attitudes towards chemistry), the pre-test and post-test mean scores of the ABCCT and the CAEQ were exposed to one-way ANOVA. Further, to go over retentional effect of the teaching interventions, the delayed-post-test mean scores of the ABCCT and the CAEQ underwent to ANCOVA by holding the post-test scores as covariate.

After verbatim transcription of the interviews, the PSTs' responses about the acid-base concepts (for the first 14 questions) were labeled into three categories: *Sound Understanding (SU)* that included all components of the validated response; Partial Understanding (*PU*) that included at least one of the components of validated response, but not all the components; and *Partial Understanding with Specific Alternative Conception (PUSAC)* that showed understanding of the concept, but also made statement which demonstrated a misunderstanding. The PSTs' responses to the remaining interview questions (the last 6 questions) were thematically analyzed in regard to their similarities and differences as suggested by Merriam (1988) and Yin (1994).

Teaching intervention

A total of the teaching intervention lasted an eight-class period (eight 50 min classes over four weeks). Because the first author, as a teaching assistant, regularly teach the 'acids-bases' subject within 'General Chemistry', she was the lecturer for all groups. Since her research interests cover design and implementation of teaching designs (e.g. 5Es learning model, REACT Strategy) to challenge the students' (alternative) conceptions, she is competent with the teaching designs under investigation. Also, because of her active participation in developing the teaching designs, she learned how to follow and implement them. Hence, it is believed that such a continuum minimizes any direct effect resulting from the instructor.

First phases of REACT and 5Es learning model intend to attract the PSTs' attention towards the related topic and to stimulate their pre-existing knowledge via different teaching materials (i.e. "acid rain" reading text in REACT strategy and "acid rain" picture in 5Es learning model). However, the first phase (Relating) of REACT strategy initially asks the PSTs to elicit "context(s)" for further learning. Indeed, this is optional for 5Es learning model. Also, the first phase (attention and motivation) of traditional/existing instruction asked the PSTs to give examples from daily life that pose their pre-existing knowledge (i.e. examples of the acids-bases). Second phases of REACT and 5Es learning model request the PSTs to conduct inquiry-based (hands-on) activities (e.g. recognizing acids-bases and measuring their pH values for REACT strategy; *Let's identify acids and bases* task for 5Es learning model) so that they are able to use their own pre-existing knowledge in order for discovering and building the new one. However, the second phase (experiencing) of REACT strategy needs to be linked to the context(s) at the first phase (e.g. *preparing a pH scale* task of the 'acid rain' reading text). This is again optional for 5Es learning model. The second phase (explanation) of the traditional/existing instruction includes a whole-class discussion and didactical teaching in which the lecturer takes an active role in knowledge building (e.g. addressing the acid-base theories--Arrhenius, Bronsted-Lowry and Lewis—and otoprotolysis of water). Their thirds phases are precisely different from each other. Third phase (applying) of REACT strategy calls the PSTs to apply their knowledge to projects, problem or laboratory tasks by connecting to the context at the first phase (i.e. Acid-base reactions in acid rain). That (explanation) of 5Es learning model asks the lecturer to (dis)confirm the PSTs' gained knowledge claims (i.e. Didactically explaining reactions in acid rain). Further, the same phase (Individual learning activities) of traditional/existing instruction includes clarification of any unclear point and solving some procedural questions (e.g. illustrating how to solve pH calculation questions). That is, the lecturer's role in REACT strategy is always mentor but 'Explanation' phase in 5Es learning model and 'Individual learning activities' in traditional/existing instruction involve in a teacher-centred procedure. Also, fourth step (cooperating) of REACT strategy contains cooperative learning on real life based problem or socio-scientific issues or science-technology-society-environment cycle given the context in the first phase (e.g. searching the question "what happens if pH value of blood increases or decreases?". The same phase (elaboration) of 5Es learning model asks the PSTs to deepen their acquired knowledge within interdisciplinary or interrelated concepts (e.g. determining acid-base strengths by electrical conductivity). Last step (Transferring) of REACT strategy engages the PSTs in transfering their knowledge into novel issues/cases (i.e. finding creative solutions for preventing the acid rain). The last phases (evaluate) of 5Es learning model and traditional/existing instruction require them to evaluate their own learning. For instance, 5Es learning model includes complementary measurument and assessment (e.g. administering a diagnostic tree of the 'acid-base' concepts) and traditional/existing instruction involves in traditional measurement and assessment (e.g. please classify each of the species as an acid or a base at the given conjugate acid-base reactions) (see Appendix 3 for an example teaching design for each group).

Because the aforementioned strategy/model include several techniques, that is, conceptual change text, hands-on activity, free writing activity, problem solving, discussion, and worksheet/experimental sheet, someone may perceive that such a teaching design could explicitly threaten measuring the effects of REACT strategy and 5Es learning model on the PSTs' conceptions and attitudes towards chemistry. However, each strategy or model is essentially alike an umbrella that covers several techniques, but any effect is directly pertaining to strategy or model instead of the techniques used (e.g., Çalık, 2013). For this reason, in this current study, it is believed that any apperant effect explicitly belongs to REACT strategy, 5Es learning model, and existing/traditional instruction.

RESULTS

Results of the first two research questions

To answer the first two research questions 'Are there any statistically significant differences between the experimental (taught by REACT strategy and 5Es learning model) and the control groups' conceptions of 'acids and bases' subject?' and 'Which of the teaching designs have the greatest effect on the PSTs' long-term memory (as retention of conceptual understanding) of 'acids and bases' subject?', data from the ABCCT and semi-structured interviews are displayed in this section.

As seen in Table 2, the pre-test mean scores of three groups ($\bar{X}_{REACT}$= 93,3, $\bar{X}_{5Es}$= 91,9, $\bar{X}_{CONTROL}$= 88,0) were close to each other. As expected, the post-test mean scores of these groups increased to 106.8, 107.7 and 97.1 respectively. Also, standard deviation values were narrower for the post-test than the pre-test of the ABCCT. For the delayed post-test, REACT and control groups' mean scores slightly increased (by 107.7and 97.7, respectively) and 5Es group's mean score slightly decreased (by 107.3) as compared with the post-test mean scores. Further, all delayed post-test mean scores were higher than those in the pre-test. Interestingly, the standard deviation values were lower for the delayed post-test than those of the pre- and post-tests of REACT and 5Es groups, however, the standard deviation value for the control one was greater for the delayed post-test than the post-test but narrower than the pre-test. The reduction in the standard deviation implies an

Table 2. Descriptive statistical analysis of the ABCCT*

Groups	N	PrT		PoT		DT	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
REACT	30	93.3	10.7	106.8	12.1	107.7	9.9
5Es	32	91.9	16.4	107.7	15.6	107.3	12.9
Control	33	88.0	14.5	97.1	7.1	97.7	13.4

PrT: Pre-test, PoT: Post-test, DT: Delayed-post-test
**: Maximum score for the ABCCT is 175 points*

Table 3. One-way ANOVA results of the ABCCT and the CAEQ

	Test	Source	degree of freedom (df)	Type III Sum of Squares	Mean Square	F	p
ABCCT	**PrT**	Between groups	2	481.5	240.8	1.2	0.3
		Within groups	92	18388.3	199.9		
		Total	94	18869.8			
	PoT	Between groups	2	2239.3	1119.6	7.7	0.0
		Within groups	92	13424.2	145.9		
		Total	94	15663.4			
CAEQ	**PrT**	Between groups	2	232.1	116.0	0.4	0.7
		Within groups	92	26299.1	285.9		
		Total	94	26531.2			
	PoT	Between groups	2	60.3	30.1	0.1	0.9
		Within groups	92	31572.5	343.2		
		Total	94	31632.7			

increase of group homogeneity.

Table 3 indicates that no meaningful statistical differences was found between the pre-test mean scores of the ABCCT (F=1.2; p >.05). Moreover, the statistical meaningful difference between the groups for the post-test mean scores (F=7.7; p <.05) reveals that the PSTs in the experimental groups outperformed those in the control group. As seen in Table 4, ANCOVA results show no significant statistical difference between the delayed post-test mean scores of the ABCCT (p >.05). Table 5 summarizes multiple comparison results for the pre-, post-, and delayed-post-test scores of the ABCCT.

There was a statistically significant difference between the post-test mean scores of REACT and the control groups; and of 5Es and the control groups in favor of REACT and 5Es groups (p <.05) (Table 5). Significant differences between the post- and the delayed-post-test mean scores of REACT and control groups; and of 5Es and control ones emerged in favor of REACT and 5Es groups (p <.05).

Table 6 summarizes the percentages of the PSTs' alternative conceptions and

Table 4. ANCOVA results for the delayed-post-tests of the ABCCT and the CAEQ

	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
ABCCT	Dependent variable: DT of ABCCT					
	Adjusted Model	6244.4(a)	5	1248.9	11.7	0.0
	Groups	89.3	2	44.6	0.4	0.7
	a R Square = .396 (Adjusted R Square= .362)					
CAEQ	Dependent Variable: DT of CAEQ					
	Adjusted Model	5427.6(a)	5	1085.5	7.9	.0
	Groups	94.5	2	47.2	.3	.7
	a R Square = .3 (Adjusted R Square = .3)					

Table 5. Multiple comparison results for the ABCCT's and the CAEQ' pre-test, post-test and delayed-post-test scores

	(I) factor1	(J) factor1	Mean difference (I-J)	Std. error	Sig.
ABCCT	**REACT PrT**	5Es PrT	1.4	3.6	0.9
		Control PrT	5.3	3.6	0.3
	5Es PrT	Control PrT	3.9	3.5	0.5
	REACT PoT	5Es PoT	-0.9	3.1	0.9
		Control PoT	9.7	3.0	0.0
	5Es PoT	Control PoT	10.6	3.0	0.0
	REACT DT	5Es DT	0.5	3.1	1.0
		Control DT	10.0	3.1	0.0
	5Es DT	Control DT	9.6	3.0	0.0
CAEQ	**REACT PrT**	5Es PrT	3.7	4.3	0.7
		Control PrT	2.9	4.3	0.8
	5Es PrT	Control PrT	-0.8	4.2	1.0
	REACT PoT	5Es PoT	-0.3	4.7	1.0
		Control PoT	1.5	4.7	0.9
	5Es PoT	Control PoT	1.8	4.6	0.9
	REACT DT	5Es DT	1.1	3.5	0.9
		Control DT	4.7	3.5	0.4
	5Es DT	Control DT	3.6	3.4	0.5

PrT: Pre-test; PoT: Post-test; DT: Delayed post-test their conceptual change rates in regard to type of the group (REACT, 5Es and control). Less than 10% of the alternative conceptions are not presented as this falls within the level of random error (e.g., Çalık, 2005). Table 7 presents the frequencies of the PSTs' responses to the interview questions.

Results of the third research question

To respond the third research question 'which of the teaching designs positively influence the PSTs' attitudes towards chemistry?' the CAEQ results and semi-structured interviews are presented in this section. There was no statistically significant difference between the groups for the pre- and post-test mean scores of the CAEQ (F=0.4, p = .7 for the pre-test and F=0.1, p = .9 for the post-test) (see Table 3). Table 8 summarizes the frequencies of the PSTs' responses of REACT strategy and 5Es learning model.

DISCUSSION

Discussion of the first two research questions

As seen in Table 2, REACT seems to achieve slightly better retention of understanding of the acid-base concepts. This may stem from linkages to the daily life and/or the PSTs' duties in the teaching intervention, for example, first-hand experiences, searching, and presenting data/information. For example, an increase or decrease in pH value of the blood may have attracted their attention to make sense of pH values and its importance for our healthy life. Given the post-test mean scores of the groups, it can also be deduced that any intervention somewhat influences the PSTs' conceptions of the acid-base chemistry.

Table 6. Percentages of the PSTs' alternative conceptions in the pre-, post- and delayed post-tests of the ABCCT

Alternative Conceptions	REACT Group				5Es Group				Control Group			
	PrT	PoT	CC	DT	PrT	PoT	CC	DT	PrT	PoT	CC	DT
Acids contain H and bases contain OH.	43.3	33.3	10.0	32.3	51.0	26.0	25.0	32.3	47.3	46.3	1.0	47.3
Acids have the opposite properties of bases.	20.0	9.0	11.0	14.3	18.7	13.7	5.0	18.7	17.3	9.0	8.3	14.0
Acids conduct electricity but bases do not.	60.0	45.7	14.3	42.3	57.3	33.7	23.7	38.7	69.7	52.7	17.0	58.7
Strength of acid-base depends on the number of H and OH in their molecules.	69.0	71.0	-2.0	67.7	68.7	69.7	-1.0	60.3	71.7	82.7	-11.0	78.7
Strong acids have greater pH value than weak ones.	47.7	41.0	6.7	31.0	38.7	39.7	-1.0	24.0	46.3	41.3	5.0	26.3
All acids make substances corrosive.	61.0	60.0	1.0	51.0	44.7	56.3	-11.7	52.0	45.3	48.3	-3.0	63.7
Plants or seeds survive unless soil is acidic.	11.0	12.3	-1.3	14.3	7.3	12.7	-5.3	13.7	6.0	8.0	-2.0	14.0
Acidity or basicity is not valid for pH=0 level.	4.3	15.7	-11.3	14.3	13.7	9.3	4.3	9.3	22.3	18.3	4.0	16.0
At pH=0, equal amounts of H^+ and OH^- ions are available in the medium.	15.7	9.0	6.7	10.0	16.7	13.7	3.0	9.3	10.0	8.0	2.0	16.0
Bronsted-Lowry only interests in conjugate acid-base pairs.	6.7	13.3	-6.7	11.0	9.3	12.7	-3.3	11.3	7.0	7.0	0.0	9.0
H^+ and OH^- ions determine the acid-base theory of Lewis.	3.3	6.7	-3.3	4.3	9.3	7.3	2.0	10.3	3.0	8.0	-5.0	9.0
Concentrated acids are always stronger than dilute ones	29.0	43.3	-14.3	30.0	35.3	39.7	-4.3	50.0	32.3	34.3	-2.0	34.3
Strong acids do not dissolve because of their strong bonds.	27.7	27.7	0.0	34.3	36.3	26.0	10.3	30.3	35.3	32.3	3.0	40.3
All salts are hydrolysable.	20.0	13.3	6.7	12.3	17.0	6.3	10.7	9.3	15.0	18.3	-3.3	17.3
All acid-base reactions do not produce salts.	4.3	12.3	-8.0	7.7	4.3	11.3	-7.0	11.3	5.0	14.0	-9.0	13.0
Molecules/Compounds with H and OH are always called neutral.	20.0	12.3	7.7	13.3	10.3	17.7	-7.3	23.0	12.0	8.0	4.0	4.0
All acids have the same molecular structure.	6.7	14.3	-7.7	11.0	9.3	12.7	-3.3	11.3	10.0	3.0	7.0	8.0
H_2O, which is a well-known solvent, does not act as an acid or base.	5.7	5.7	0.0	11.0	9.3	13.7	-4.3	12.7	8.0	21.3	-13.3	17.3
Average Conceptual Change			0.53				1.97				0.15	

CC: Conceptual Change.

Table 7. Frequencies of the PSTs' responses to the interview questions

Interview Question	Categories	REACT	5Es	Control	Sample quotations for PUSAC
What is the acid? What is the base? How do you understand whether a substance is an acid or a base?	SU	5	4	1	Ions that can receive H electrons are called as acids. The substances that can donate electron ions are named as bases. If the litmus paper is red, it is called as an acid. If the litmus paper is blue, it is called as a base.
	PU	0	0	2	
	PUSAC	1	2	3	
What can you say about such acid-base theories as Arrhenius, Bronsted-Lowry and Lewis?	PU	1	1	0	In Arrhenius, the substance that can receive H^+ ions is named as an acid whereas the one that can donate OH^- ions to the water is called as a base. In Bronsted-Lowry, the substance that donates electron pairs is called as a base whilst the one that receive the electron pairs is named as an acid.
	PUSAC	4	4	3	
How do you measure the acidity and basicity? What does this measure mean?	PU	2	1	3	If we get acids and bases reacted, the number of OH^- ions identifies pOH value. Further, the number of H^+ ions determines pH value, and so we can learn strength of acidity and pH value.
	PUSAC	3	3	3	
How does an increase in pH value affect the acidity? Please defend you response	SU	1	1	0	The pH value affects the acidity. There is a direct proportional relationship between acidity and pH value.
	PU	5	2	3	
	PUSAC	0	3	3	
How does an increase in pOH influence the basicity? Please defend you response	PU	1	0	1	The pOH value influences basicity because it gives more OH^- ions to the water.
	PUSAC	5	5	5	
What is the relationship between pH and pOH?	PU	6	6	6	-
Please compare the acidity strengths of H_3PO_4 and HI.	PU	2	2	0	They have different acidity strengths. The strength of H_3PO_4 is greater because it contains more H^+ ions that make more bonds. The more it contains H^+ ions the more the acidity strength enhances.
	PUSAC	4	4	6	
Could you compare the acidity strengths of 1M HCl and 3M HCl. What does the strength of acidity-basicity depend on?	PU	1	1	0	The acidity strength of 3M HCl is greater because acid-base strength depends on the groups at the periodical table. For example, strength of group 1A is greater.
	PUSAC	4	2	3	
What is polyprotic acid? Could you give a few sample polyprotic acids? How do you determine the polyprotic acid?	PU	3	3	0	The polyprotic acid can react more. We can determine the polyprotic acid using Lewis and Arrhenius acid-base theories.
	PUSAC	0	0	3	
What do you think about electrical conductivity of acid-base? How does electrical conductivity of acid-base count on?	PU	4	5	4	Acids do not conduct electricity but bases do. It depends on the element's conductivity.
	PUSAC	2	1	2	
Where do you encounter the acids-bases in your daily life? Do you know any food that contains acid or base? If Ok, could you give some examples?	SU	4	5	4	Spring water sold in bottle has pH values, e.g. 7, 7.8 or 8. Shampoos are acidic. I could not remember completely whether an apple and a grape have sugar acids or folic acid.
	PUSAC	2	1	2	
Do you think that the acids-bases are dangerous? Please defend you response	SU	2	1	0	-
	PU	4	5	3	
Could you explain what happens in the acid-base reaction? What is the neutralization? What is the salt?	PU	4	6	3	The acid-base reaction forms salt and water. Neutralization means equal amount of OH^- and H^+ ions. When the salt is dissolved, it can be hydrolyzed.
	PUSAC	2	0	0	
What is the hydrolysis? Do you think that all salts are hydrolysable? Please defend your response with examples?	PU	3	4	1	Hydrolysis is an electrical decomposition. All salts are not hydrolysable. For example neutral salts, NaCl.
	PUSAC	3	2	4	

SU: Sound understanding; PU: Partial understanding; PUSAC: Partial understanding with specific alternative conception

Table 8. Frequencies of the PSTs' responses of REACT strategy and 5Es learning model

Question	Themes	REACT Group	5Es Group
What do you think about the difference(s) between REACT strategy/5Es learning model and traditional instruction? Please explain your response.	Active student engagement	3	1
	Enjoyable and/or funny	1	1
	Formative assessment via worksheets	1	-
	Illustrative activities that work for conceptual understanding /permanent learning	1	2
	Intensive treatment of the acid-base topic	2	-
	Preliminary preparation	-	2
	Dismal measurements with pre-, post- and delayed post-tests	1	-
Given the teaching designs (REACT/5Es and traditional/existing instruction), which one would you like to follow? Please explain your response.	Student-centered	5	3
	Dependent on the context/situation	1	3
Would you like to learn your ongoing chemistry classes via REACT strategy or 5Es learning model? Please explain your response.	Yes, because it is so fruitful	6	5
	Yes, because it encourages students to study themselves	-	1
Do you think the teaching intervention (REACT strategy or 5Es learning model) includes any pitfall that needs to be revised? Please explain your response.	No pitfall	3	4
	Revising student role in finding the experiment tools instead of prepared one	1	-
	Increasing the number of collaborative presentations	1	-
	More guidance in doing experiment	1	-
	Improper for my learning style	-	1
	Increasing student responsibility, e.g. preliminary preparation	-	1
What do you think about the advantage(s) of the teaching intervention you had attended? Please explain your response.	Awareness of my own learning potential	3	-
	Linking the chemistry topics to everyday life	1	1
	Learning how to learn	2	1
	Experiencing group work	1	-
	Conceptual/ permanent learning	-	2
	Revising any missing/unclear point	-	2
What do you think about the (dis)advantage of the group work in your class? Please explain your response.	Knowledge construction	3	5
	Socialization	2	2
	Cooperation problem through our group work	1	-

Because no meaningful statistical difference was found between the pre-test scores (see Table 3), this may also be viewed as a significant advantage for comparing any effect of independent variable on dependent one, specifically, the effects of teaching designs on the PSTs' conceptions. This also indicates that the PSTs brought their previous conceptions to the learning environment (e.g. Novak, 1988). In a similar vein, this means that the PSTs almost had similar pre-existing knowledge. The statistical difference between the groups in post-test scores may likely have been caused by the frameworks of REACT strategy and 5Es learning model, for example, the student-centered teaching design and context-based issues. Likewise, this suggests that any teaching intervention different from the conventional or existing instruction seems to stimulate the PSTs' attention/interest to the topic under investigation (e.g. Marks, Bertram & Eilks, 2008; Saka, 2011; Ültay, Durukan & Ültay, 2015).

As seen in Table 4, no significant statistical difference between the delayed post-test mean scores implies that the teaching interventions were effective at enabling the PSTs to retain their conceptions of the acid-base chemistry in long-term memory. The fact that REACT strategy and 5Es learning model had positive effects on conceptual understanding (see Table 5) is consistent with previous studies, for example, CORD (1999) and Özmen, Demircioğlu and Coll (2009). No significant difference between the post-test mean scores of REACT and 5Es groups may shed light on the PSTs' curiosity of varied teaching designs that differ from their familiar ones. That is, the PSTs seem to have paid more attention to student-centred teaching designs that trigger their inquisitiveness to learn. In addition, REACT strategy and 5Es learning model have resulted in better retention of the acid-base concepts.

The alternative conception "acids contain H and bases contain OH" (see Table 6) (e.g. Çetingül & Geban, 2005; Nakhleh & Krajcik, 1994; Üce & Sarıçayır, 2002) may stem from their daily life experiences and/or textbooks (i.e. Hazer, 1995; Petrucci, 1989) that tend to exploit such acid-base examples as HNO_3, CH_3COOH, HCOOH, NaOH, KOH. The PSTs' responses to the first interview question (see Table 7) support this proposition. Phrased differently, the PSTs seem to have integrated the acid and/or acidity with the existence of hydrogen. For instance, a molecule or compound with hydrogen atom(s) is always called *acid* in that molecular structures of the acids should be the same. In point of this view, NH_3 is an acid, not a base. The conceptual change rates of REACT strategy and 5Es learning model indicate a significant improvement in overcoming this alternative conception, but does not completely diminish it. This means that the teaching interventions change the conflict in the mind between the scientific and alternative conceptions, however, a new cognitive balance between them requires more time. Hence, the dominant conception in this cognitive process identifies the balance in favor of the scientific or alternative conception. For this alternative conception, the balance in the cognitive process seems to be in favor of the scientific conception from REACT strategy and 5Es learning model. In a similar vein, the PSTs' responses to the first interview question were more satisfied for REACT and 5Es than the control group. Also, given their percentages of the delayed post-test, the alternative conception ratio shifts were the same for the traditional/existing instruction, a slightly decrease for REACT strategy, and a slightly increase in 5Es learning model. This may indicate that the hard-core alternative conceptions are too robust to change via any teaching design (e.g., Guzzetti, Williams, Skeels & Wu, 1997; Kolomuç & Çalık, 2012). This may further indicate that the hard-core alternative conception tend to cause the PSTs to be closed-minded (instead of open-minded) to scientific concepts (e.g., Çalik & Coll, 2012; Çalık, Turan & Coll, 2014; Lakatos, 1970). The high conceptual change rate for 5Es group may be an outcome of the activities and function of third step (explanation) in which the lecturer actively discussed the acid-base concepts (e.g. Kılavuz, 2005). Likewise, discussion function in 5Es learning model may have acted as a significant role in achieving the conceptual understanding of the acid-base chemistry. Zhang (2014, p. 8) addresses functional role of discussion with this statement: *"With discussion functions, the probability of achieving gains in scientific explanations is about 7 times greater than without this feature"*. However, such a gain seems to have somewhat lost in the delayed post-test (see Table 6).

The alternative conception 'acids have the opposite properties of bases' may stem from misinterpretation of the neutralization process. Another reason may be their existing alternative conceptions, for example, the alternative conception 'acids conduct electricity but bases do not' (e.g. Çetingul & Geban, 2005) may come from the idea 'electrical conductivity depends on H^+ ions in acids or acid solutions'. These alternative conceptions in the post-test significantly decreased for all groups, but were not completely eliminated. A conceptual improvement in 5Es and REACT groups may result from the 'determination of strengths of acids and bases with electrical conductivity' activity. Also, the high performance for the control group may have stemmed from knowledge construction role of the whole-class discussion (e.g., Çalik, Özsevgeç, Ebenezer, Artun, & Küçük, 2014; Zhang, 2014). Given Cleghorn, Shumba, and Peacock's (2002) study that learning revolves through several characteristics, for example, prior understanding, interaction style, social class position, views of authority, and ethnicity, the PSTs in the control group may already have learned the focal topic prior to the test. Percentages of these alternative conceptions in the delayed post-test (see Table 6) showed an inconsistent trend depending on the type of alternative conception.

The alternative conception ‘strength of acid-base depends on the number of H and OH in their molecules’ (e.g. Çetingül & Geban, 2005; Özmen et al., 2009) may have derived from the idea that ‘the more hydrogen and hydroxide in the molecules increase, the more their strengths do’. This means that the PSTs seem to have confused the number of H^+ or OH^- ions in the solutions with those in the molecules. The interview results also support this confusion (see Table 7). During interviews, most of the PSTs implied that H_3PO_4 was stronger because it contained more H^+ ions. Interestingly, all teaching interventions used in the current study triggered this alternative conception in the post-test (see Table 6). The PSTs might think that all acids and bases completely (100%) ionize (e.g. Gökçek, 2007). This also confirms that hard-core alternative conceptions tend to be dominant in the cognitive learning process (Lakatos, 1970) and resistant to change (e.g. Guzzetti et al., 1997). REACT strategy and 5Es learning model reduced this alternative conception in the delayed post-test in comparison to the pre- and the post-tests, however, the resistance to change in the control group was still high in regard to the pre-test. This means that REACT strategy and 5Es learning model via ‘determination of acid-base strength by the electrical conductivity’ activity at least had the potential to influence the PSTs’ retention of the ‘strength of acid-base’ concept. Similarly, as seen in Table 7, a few interviewees in these groups tended to link the strength of the acid-base with ionization.

Another alternative conception ‘strong acids have greater pH value than weak ones’ may stem from correlating pH scale with the strength of acid. That is, the PSTs may have considered that the greater the strength of acid is, the higher the pH value is. Such a result is supported by Çetingül and Geban (2005), and Özmen et al. (2009). For example, some interviewees perceived a direct proportional relationship between the acidity and pH value (see Table 7). But the PSTs-created pH scale (for REACT group) and procedural learning, for example, algorithmic problem solving (for the control group) seem to have assisted the PSTs in remedying this alternative conception. For the control group, the procedural learning may somehow have underpinned the conceptual understanding. Surprisingly, 5Es learning model had unsuccessful dealing with this alternative conception after the teaching intervention. REACT and control groups achieved the conceptual change to some extent. But their retentional effects appeared better in the delayed post-test. The other alternative conception ‘all acids make substances corrosive’ (e.g. Çetingül & Geban, 2005) may result from their daily life experiences, for example, the news/media about house accidents, effect of acid rain on the wildlife and crops, and movies on volcanic explosion/eruption. In the interview data (see Table 7), even though the PSTs grasped the usages of acids and bases in daily life, they still thought that all acids were corrosive. Unfortunately, except for REACT strategy, the other teaching interventions enhanced this alternative conception in the post-test and delayed post-test. This depicts that 5Es learning model and traditional/existing instruction were ineffective at overcoming this alternative conception. Another alternative conception ‘because plants or seeds survive unless soil is acidic’ may have come from interactions with such alternative conceptions as ‘all acids make substances corrosive’. Notably, any teaching intervention did not reduce its percentages in the post-test and delayed post-test, rather it seemed to have reinforced this alternative conception. This indicates that if the alternative conceptions are reinforced with daily life experiences, its resistance to change strengthens (e.g. Özmen, 2003; Bozkurt et al., 2005). That is, such a process may hammer the alternative conception in the mind/cognitive learning process as a hard-core issue (Ross & Munby, 1991). Overall, daily life examples in the teaching interventions (as context) may have made this alternative conception inadvertently resistant to change.

The alternative conception 'acidity or basicity is not valid for pH=0 level'" (e.g. Çetingül & Geban, 2005) may stem from the idea 'H^+ or OH^- ions are absent in this medium'. In a similar vein, PSTs may have an inability to imagine or algorithmically calculate the pH=0 issue (Banerjee, 1991). Likewise, some PSTs' responses to the questions 4-5 (see Table 7) reveal inability to visualize how the pH values are relevant with the concentration of H^+ ions in the solution. Taking percentages of the post-test scores and conceptual change rates into consideration, REACT strategy enhanced this alternative conception but 5Es learning model and traditional/existing instruction reduced this one. In fact, this may have resulted from the teaching intervention. For example, the lecturer solved several algorithmic problems in the *Explanation* step of 5Es learning model and traditional/existing instruction but the PSTs were required to solve such problems themselves for REACT strategy. This highlights the link between conceptual understanding and algorithmic learning/procedural learning (see Table 6).

The alternative conception 'at pH=0, equal amounts of H^+ and OH^- ions are available in the medium' may stem from their use of a pH scale that starts with pH=1 level. For this reason, the conceptual change achieved may result from the PSTs' curiosity of meaning of pH=0 level. Our informal observation reveals that some of the PSTs asked and explored this issue further after the pre-test.

As can be seen in Table 6, the PSTs possessed two principal alternative conceptions of the acid-base theory addressed by earlier studies: Bronsted-Lowry only interests in conjugate acid-base pairs; H^+ and OH^- ions determine the acid-base theory of Lewis (e.g. Carr, 1984; Furió-Más, Calatayud, Jenaro Guisasola, & Furió-Gómez, 2005).This may result from a lack of remembering or confusing the names of the acid-base theory (Bronsted-Lowry and Lewis). That is, they may have paid more attention to what the acid-base theories describe rather than their names. The alternative conception 'concentrated acids are always stronger than dilute ones' (e.g. Özmen et al., 2009; Üce & Sarıçayır, 2002) may have resulted from confusion between the concepts of 'strength and concentration'. Similarly, this seems to resonate in the interview data where the majority of the interviewees (see Table 7) still thought that the acid-base strength depended on the concentration. Interestingly, any current teaching intervention used did not enable the PSTs to deal with this alternative conception. This may stem from a decrease in their motivation and interests towards the teaching interventions.

Another alternative conception 'strong acids do not dissolve because of their strong bonds' (i.e. Özmen et al., 2009) may result from a lack of understanding interrelated concepts (e.g., dissolution, chemical bonding and acid). In parallel with the ABCCT, the interviewees addressed that the more bonds the acid possessed the greater its strength was (see Table 7). This suggests that REACT strategy and 5Es learning model of the acid-base chemistry should have taken interrelated alternative conceptions into account. The alternative conception 'all salts are hydrolysable' (e.g. Çalık, 2005) may come from confusion with the concept of 'hydrolyze and dissolution'. Further, this alternative conception seems to have grown into a new alternative conception of 'H_2O, which is a well-known solvent, does not act as an acid or base'. That is, they may consider that water has only one role in dissolving/dissolution phenomenon, not in the acidity and basicity. In regard to the post-test scores and conceptual change rates, REACT strategy and 5Es learning model reduced the PSTs' alternative conceptions. For instance, involving a conceptual change text in *Elaboration* phase of 5Es learning model may explicitly have helped the PSTs remedy this alternative conception to some extent.

Another alternative conception 'molecules/compounds with H and OH are always called neutral' and 'all acid-base reactions do not produce salts' may have resulted from a lack of understanding of 'strong acid, weak acid, strong base, weak base and neutralization' concepts. That is, they may have considered that all acids and bases reactions produce neutral salts without considering acidic and basic salts. REACT strategy and traditional/existing instruction somewhat eliminated this alternative conception but 5Es learning model posed it in the post-test and delayed post-test. The whole-class discussion and presentation in REACT group seem to have facilitated the PSTs' conceptual change of this alternative conception. Moreover, an increase in this alternative conception for 5Es group may come from acetic acid (CH_3COOH) used in the activity.

To sum up, average conceptual change values were found to be 0.53 for REACT group, 1.97 for 5Es group and 0.15 for control group. Positive average changes for all groups indicate that the teaching interventions somewhat helped the PSTs remedy their alternative conceptions of 'acid-bases' topic. Phrased differently, even though REACT strategy and 5Es learning model resulted in better conceptual change than did traditional/existing instruction, their effects were dramatically limited to replace the PSTs' alternative conceptions with the scientific ones.

Discussion of the third research question

The teaching interventions used in the current study were ineffective in positively changing the PSTs' attitudes towards chemistry (see Tables 3-5). This may be caused by the structure of the CAEQ, which is more sensitive than a 4 or 5 Likert type scale (e.g. Geban, Ertepınar, Yılmaz, Altan & Tahpaz, 1994; Sunger, 2007). Also, the CAEQ measures specific factors (e.g., chemists, chemistry research, and chemistry jobs) rather than general attitudes towards chemistry/science. Furthermore, this may stem from Turkish PSTs' school culture or habits of teacher-centered instruction (as passive receptors) instead of constructing their own knowledge (at student-centered learning) via scientific inquiry. It was observed that the PSTs appeared 'bored' with such an active learning environment and complained about their responsibilities of the teaching interventions at the experimental groups.

No statistically significant difference was found between the groups for the delayed post-test of the CAEQ (Tables 5-6). This may result from ongoing instruction which was not systematically planned within 5Es learning model and REACT strategy. This calls for a long-term teaching period with inquiry-based learning (REACT strategy and 5Es learning model).

A lack of enhancing the PSTs' attitudes towards chemistry is inconsistent with the related literature reporting that 5Es learning model (e.g. Gerber, Cavallo & Marek, 2001; Özsevgeç, 2007) and context-based approach (e.g. Bennett & Lubben, 2006; Demircioğlu et al., 2009; Graber, Erdmann & Schlieker, 2002) tended to positively change the student attitudes and motivation towards science/chemistry. In contrast of the results of the CAEQ, majority of the interviewees from REACT and 5Es groups (see Table 8) indicated positive attitudes about the teaching interventions. This contrast may have stemmed from the CAEQ structure with more specific statements that differ from standard scales with ordinary statements (i.e., I like science/chemistry; I enjoy studying on science/chemistry). It may also stem from the freshman sample's study habits. For example, most of the PSTs may have lacked of working systematically as suggested by REACT strategy and 5Es learning model. In a similar vein, their principal concerns may have been the exam and its content, not learning acid-base chemistry. The interview themes 'Intensive treatment of the acid-base topic', 'Dismal measurements with pre-, post- and delayed post-tests', 'Preliminary preparation', and 'Improper for my learning style' indicates this possibility of the PSTs' study habits (see Table 8).

In parallel with previous context-based and 5Es studies (e.g. Bennett & Lubben, 2006; Graber et al., 2002), most of the interviewees under investigation tended to be particularly keen on learning the subsequent chemistry lessons through the student centered learning environments (e.g., REACT strategy and 5Es learning model) (see Table 8). Overall, all themes, except for a few attitudes/experiences/feelings, denoted the PSTs' positive attitudes towards chemistry. Such an inconsistency between the CAEQ and the interview data may stem from the data collection instruments. For example, face-to-face structure of the interview protocol may have been more effective at uncovering the PSTs' real attitudes towards chemistry. Alternatively, the PSTs may have held dual perceptions/attitudes that were similar to dual conceptions stated by Gilbert, Osborne and Fensham (1982) or apartheid by Cobern (1996). That is, their attitudes may be dependent on the type of data collection instruments.

CONCLUSIONS AND IMPLICATIONS FOR PRACTICE AND LEARNING

The results shed further light on current understanding reported in relevant literature arguing that any instruction only influences instruction-based alternative conceptions (Demircioğlu, Dinç & Çalık, 2013; Karslı & Çalık, 2012). Similarly, it can be concluded that any instruction with the sheer force of scientific conceptual weight tends to modify 'soft-core' alternative conceptions (Cobern, 1996; Lakatos, 1970). Furthermore, overgeneralization of the acid-base theories (i.e. Arrhenius acid-base theory) seems to have triggered such alternative conceptions as 'acids contain H and bases contain OH'. Also, daily life experiences somehow tend to support alternative conceptions and make them more robust to being replaced with scientific concepts despite the context-based approach (see Table 6). In other words, some hard-core alternative conceptions ('all acids make substances corrosive' and 'plants or seeds survive unless soil is acidic') that are deeply rooted in the PSTs' cognitive structures are still resistant to alter (Lakatos, 1970).

The highest conceptual change values for the alternative conception 'acids conduct electricity but bases do not' may stem from hands-on POE activities (e.g. Determining acid-base strengths by electrical conductivity) challenging this alternative conception. This advocates Bodner's (1990) view of conceptual change that persuades the students to construct a more plausible conception rather than alternative one. Average conceptual change values (see Table 6) reveal that a critical mass of conceptual change seems to have unveiled the PSTs' compartment walls for scientific knowledge; but reorienting the cognitive apartheid between the alternative conceptions and scientific ones still needs much more time and/or ongoing activities (e.g. Cobern, 1996). As a matter fact, the ABCCT and interview data suggest that the PSTs' newly generated conceptions should have been reinforced with ongoing instruction.

Interestingly, even though an increase in the PSTs' attitudes towards chemistry was expected for REACT group, the current study did not proof any statistical effect for the Turkish context. This means that cultural borders, habits, or worldviews may have had a greater impact on the Turkish PSTs' attitudes and priorities rather than REACT strategy originated from the USA context. Otherwise, it can be inferred that the 4-week intervention period is not enough to quantitatively challenge the PSTs' attitudes towards chemistry (Çalik et al., 2014; Kılavuz, 2005). Furthermore, this may come from a positive attitudinal transition to science teacher education programme (i.e. Çalık et al., 2015). For instance, the high-staking nation-wide examination (in the final-year of upper secondary science education) may have enhanced their preparedness and/or awareness levels of the 'chemistry jobs' subscale. After the teaching interventions, no results of negative attitudinal impacts at the CAEQ can at least be viewed as a promising issue to improve the PSTs' chemistry attitudes to a quantitatively satisfied level. A lack of significant attitudinal change towards chemistry may result from the teaching interventions that implicitly deployed the subscales of the CAEQ (e.g. *chemists, chemistry research and chemistry jobs)*. That is, embedding explicitly these subscales within the teaching interventions may have resulted in significant improvements towards chemistry. This may be seen as a limitation of the current study.

The foregoing results reveal that REACT strategy and 5Es learning model (originally launched in the USA) need to be revised for Turkish context. However, a longitudinal study should be implemented on how to revise and/or expand them. Similarly, future studies, which will test the effects of REACT strategy and 5Es learning model on different variables (i.e. sample, subject, scientific process skills, scientific inquiry) over a longer period of time (i.e. one semester or one-year), may be very fruitful to get insights of their effectiveness.

ACKNOWLEDGEMENT

We would like to thank Dr. Karsten Zegwaard from University of Waikato, New Zealand for his assistance with this publication.

AUTHORS' NOTE

This study is a part of Dr. Neslihan Ültay's PhD thesis entitled "Designing, Implementing and Comparing "Acids and Bases" Instructional Tasks Based on REACT Strategy and 5Es Model"

REFERENCES

Abraham, M. R., Gryzybowski, E. B., Renner, J. W., & Marek, A. E. (1992). Understanding and misunderstanding of eighth graders of five chemistry concepts found in textbooks. *Journal of Research in Science Teaching*, *29*, 105-120.

Banerjee, A. C. (1991). Misconceptions of students and teachers in chemical equilibrium. *International Journal of Science Education*, 13(4), 487-494.

Barker, V., & Millar, R. (1999). Students' reasoning about chemical reactions: What changes occur during a context-based post-16 chemistry course? *International Journal of Science Education*, *21*(6), 645-665.

Barker, V., & Millar, R. (2000). Students' reasoning about basic chemical thermodynamics and chemical bonding: What changes occur during a context-based post-16 chemistry course? *International Journal of Science Education*, *22*(11), 1171- 1200.

Bennett, J., & Lubben, F. (2006). Context-based chemistry: The salters approach. *International Journal of Science Education*, *28*(9), 999-1015.

Berns, R. G., & Erickson, P. M. (2001). Contextual teaching and learning: Preparing students for the new economy. *The Highlight Zone Research Work*, *5*, 1-8.

Bilgin, İ. & Yahşi, D. (2006). *Farklı laboratuvar yaklaşımlarının ilköğretim 8.sınıf öğrencilerinin asit-baz konularındaki kavramları anlamalarına etkisinin incelenmesi (Investigating the effects of various laboratory approaches* on grade 8 students' conceptions of acid-base concepts). Paper presented at Seventh National Science and Mathematics Education Congress, Gazi University, September 7-9, Ankara (In Turkish).

Bodner, G.M. (1990). Why good teaching fails and hard-working students don't always succeed. *Spectrum, 28*(1), 27-32.

Botton, C. (1995). Collaborative concept mapping and formative assessment key stage 3: Understandings of acids and bases. *School Science Review*, *77*, 124-130.

Bozkurt, O., Aydın, H., Yaman, S., Uşak, M., & Gezer, K. (2005). Sixth, seventh and eighth year students' knowledge levels about greenhouse effect, ozone layer and acid rain. *Mediterranean Journal of Educational Sciences*, *10*(2), 81-95.

Bradley, J. D., & Mosimege, M. D. (1998). Alternative conceptions in acids and bases: A comparative study of student teachers with different chemistry backgrounds. *South African Journal of Chemistry*, *51*, 137-147.
Bulte, A. M. W., Westbroek, H. B., de Jong, O., & Pilot, A. (2006). A research approach to designing chemistry education using authentic practices as contexts. *International Journal of Science Education*, *28*(9), 1063-1086.
Burhan, Y. (2008). *Asit ve baz kavramlarına yönelik karikatür destekli çalışma yapraklarının geliştirilmesi ve uygulanması (Developing worksheets enriched by concept cartoons concerning the acid-base concepts)*. Unpublished Master Thesis, Karadeniz Technical University, Trabzon, Turkey (In Turkish).
Bybee, R. W. (2003). *Why the seven E's*. http://www.miamisci.org/ph/lpintro7e.html
Bybee, R. W., Taylor, J. A., Gardner, A., van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). *The BSCS 5E instructional model: Origins and effectiveness*. A Report Prepared for the Office of the Science Education National Institutes of Health http://science.education.nih.gov/houseofreps.nsf/b82d55fa138783c2852572c9004f5 5 66/$FILE/Appendix%20D.pdf
Carr, M. (1984). Model confusion in chemistry. *Research in Science Education*, *14*, 97-103.
Cho, J. (2002). The development of an alternative in-service programme for Korean science teachers with an emphasis on science-technology-society. *International Journal of Science Education*, *24*(10), 1021-1035.
Cleghorn, A., Shumba, O. & Peacock, A. (2002). Education students' views towards science for children: Canada, Zimbabwe, England comparisons. *World Studies in Education*, *3*(2), 103-118.
Cobern, W.W. (1996). Worldview theory and conceptual change in science education. *Science Education*, *80*(5), 579-610.
CORD, (1999). *Teaching science contextually*. CORD Communications, Inc., Waco, Texas, USA.
Cokelez, A. & Dumon, A. (2009). A comparative study of French and Turkish students' ideas on acid-base. *Procedia Social and Behavioral Sciences, 1*, 536-537.
Crawford, M. L. (2001). *Teaching contextually: Research, rationale, and techniques for improving student motivation and achievement in mathematics and science*. CCI Publishing, Waco, Texas, USA.
Creswell, J. W. (2003). *Research design: Qualitative, quantitative and mixed methods, approaches* (2nd Ed.). Sage Publications, United States of America.
Çalık, M. (2013). Effect of technology-embedded scientific inquiry on senior science student teachers' academic self-efficacy. *Eurasia Journal of Mathematics*, *Science & Technology Education, 9*(3), 223-232.
Çalık, M. & Ayas, A. (2005). A comparison of level of understanding of grade 8 students and science student teachers related to selected chemistry concepts. *Journal of Research in Science Teaching*, *42*(6), 638-667
Çalık, M. & Aytar, A. (2013). Investigating prospective primary teachers' pedagogical content knowledge of "effect of human on environment" subject in the process of teaching practice. *Kuram ve Uygulamada Eğitim Bilimleri*, *13*(3), 1579-1605
Çalik, M. & Coll, R.K. (2012). Investigating socioscientific issues via scientific habits of mind: Development and validation of the scientific habits of mind survey (SHOMS). *International Journal of Science Education,* 34(12), 1909-1930.
Çalık, M. (2005). A cross-age study of different perspectives in solution chemistry from junior to senior high school. *International Journal of Science and Mathematics Education, 3*, 671–696
Çalik, M., Özsevgeç, T., Ebenezer, J., Artun, H. & Küçük, Z. (2014). Effects of 'environmental chemistry' elective course via technology embedded scientific ınquiry model on some variables. *Journal of Science Education and Technology, 23*(3), 412-430.
Çalık, M., Turan, B. & Coll, R.K. (2014). A cross-age study of elementary student teachers' scientific habits of mind concerning socioscientific issues. *International Journal of Science and Mathematics Education, 12*(6), 1315-1340
Çalik, M., Ebenezer, J., Özsevgeç, T., Küçük, Z. & Artun, H. (2015). Improving science student teachers' self-perceptions of fluency with innovative technologies and scientific inquiry abilities. *Journal of Science Education and Technology, 24*(4), 448-460. doi: 10.1007/s10956-014-9529-1

Çalık, M., Ültay, N., Kolomuç, A. & Aytar, A. (2015). A cross-age study of science student teachers' chemistry attitudes. *Chemistry Education: Research and Practice, 16*(2), 228-236 doi: 10.1039/c4rp00133h

Çetingul, P. I., & Geban, O. (2005). Understanding acid-base concept by using conceptual change approach. *Hacettepe University Journal of Education*, *29*, 69-74.

Dalgety, J., Coll, R. K., & Jones, A. (2003). Development of chemistry attitudes and experiences questioannaire (CAEQ). *Journal of Research in Science Teaching*, *40*(7), 649-668.

Demircioğlu, G. (2003). *Lise II asitler ve bazlar ünitesi ile ilgili rehber materyal geliştirilmesi ve uygulanması (Developing and implementing teacher guide materials related to the unit "acids and bases" at lycee-II)*. Unpubslihed PhD Thesis, Karadeniz Technical University, Trabzon, Turkey (In Turkish).

Demircioğlu, H., Demircioğlu, G., & Çalık, M. (2009). Investigating effectiveness of storylines embedded within context based approach: A case for the periodic table. *Chemistry Education Research and Practice*, *10*(3), 241-249.

Demircioğlu, H., Dinç, M. & Çalık, M. (2013). The effect of storylines embedded within context-based learning approach on grade 6 students' understanding of 'physical and chemical change' concepts. *Journal of Baltic Science Education, 12*(5), 682-691.

Demircioğlu, G., Özmen, H. & Ayas, A. (2004). Asit ve baz kavramları üzerine bir araştırma çerçevesinde kimyada karşılaşılan kavram yanılgıları (A research on misconceptions of acid-base concepts). *Kuram ve Uygulamada Eğitim Bilimleri, 4*(1), 57-80 (In Turkish).

Demircioğlu, H., Vural, S., & Demircioğlu, G. (2012). The effect of a teaching material developed based on "REACT" strategy on gifted students' achievement. *Journal of Ondokuz Mayıs University Faculty of Education*, *31*(2), 101-144 (In Turkish).

Drechsler, M., & Driel, V. J. (2008). Experienced teachers' pedagogical content knowledge of teaching acid-base chemistry. *Research in Science Education*, *38*(5), 611-631.

Driel, V. J. H. (2005). The conceptions of chemistry teachers about teaching and learning in the context of a curriculum innovation. *International Journal of Science Education*, *27*(3), 303-322.

Driver, R. (1981). Pupils' alternative frameworks in science. *European Journal of Science Education*, *3*, 93-101.

Eisenkraft, A. (2003). Expanding the 5E model. *The Science Teacher*, *September*, 56-59.

Ekmekçioğlu, E. (2007). *Ortaöğretim kimya dersinde asit baz konusunun anlamlı öğrenme kuramı ve kavram haritası ile öğretiminin başarıya etkisi (The effect of meaningful learning theory and teaching with concept map to achievement of acid-base topic in chemistry lessons at high schools)*. Unpublished Master Thesis, Selçuk University, Konya, Turkey (In Turkish).

Er Nas, S., Coruhlu, T. S. & Cepni, S. (2010). An assessment on the effectiveness of the material developed for the elaborate stage of the 5E model. *Journal of Ondokuz Mayıs University Faculty of Education*, *29*(1), 17-36 (In Turkish).

Erduran, S. (2003). Examining the mismatch between pupil and teacher knowledge in acid-base chemistry. *School Science Review, 84*(308), 81-87.

Feng, S. L., & Tuan, H. L. (2005). Using ARCS model to promote 11th graders' motivation and achievement in learning about acids and bases. *International Journal of Science and Mathematics Education*, *3*(3), 463-484.

Furió-Más, C., Calatayud, M. L., Jenaro Guisasola, J., & Furió-Gómez, C. (2005). How are the concepts and theories of acid–base reactions presented? Chemistry in textbooks and as presented by teachers. *International Journal of Science Education*, *27*(11), 1337-1358.

Garnett, P. J., & Tobin, K. (1988). Teaching for understanding: Exemplary practices in high school chemistry. *Journal of Research in Science Teaching*, *26*, 1-14.

Geban, Ö., Ertepınar, H., Yılmaz, G., Altan, A. & Tahpaz, F. (1994). *Bilgisayar destekli eğitimin öğrencilerin fen başarılarına ve fen bilgisi ilgilerine etkisi (Effects of computer aided instruction on students' science achievement and interests towards science)*. Paper presented at First National Symposium of Science Education, Dokuz Eylul University, İzmir, Turkey (In Turkish).

Geban, Ö., Taşdelen, U. & Kırbulut, Z. D. (2006). *Kavramsal değişim yaklaşıma dayalı ortak grup çalışmalarının asit-baz kavramlarını anlamaya etkisi*. *(The effect of cooperative group works based on conceptual change approach on understanding of acid-base concepts).* Paper presented at Seventh National Science and Mathematics Education Congress, Gazi University, September 7-9, Ankara (In Turkish).

Gerber, B. L., Cavallo, A. M. L., & Marek, E. A. (2001). Relationship among informal learning environments, teaching procedures, and scientific reasoning abilities. *International Journal of Science Education*, *23*(5), 535-549.

Gilbert, J. K. (2006). On the nature of "context" in chemical education. *International Journal of Science Education*, *28*(9), 957-976.

Gilbert, J. K., Osborne, J. R. ve Fensham, P. J. (1982). Children's Science and Its Consequences for Teaching. *Science Education*, *66*(4), 623-633.

Glynn, S. M., & T. R. Koballa, Jr. (2005). *The contextual teaching and learning instructional approach, exemplary science: Best practices in professional development*. In R. E. Yager (ed.) (pp 75-84). NSTA press, Arlington, VA, USA.

Gokcek, N. (2007). *İlköğretim 8. sınıf öğrencilerinin asit baz konusundaki başarılarına çoklu zeka kuramının etkisinin araştırılması (The effect of the multiple intelligences theory on grade-8 students` achievement in the topic of acid and base)* (Unpublished master thesis). Gazi University, Ankara, Turkey (In Turkish).

Graber, W., Erdmann, T., & Schlieker, V. (2002). *ParCIS: Partnership between chemical industry and schools*. Paper presented at the 2nd International IPN – YSEG Symposium, Kiel, Germany.

Guzzetti, B. J., Williams, W. O., Skeels, S. A., & Wu, S. M. (1997). Influence of text structure on learning counterintuitive physics concepts. *Journal of Research in Science Teaching*, *34*(7), 701-719.

Hair, J. F. Jr., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2006). *Multivariate data analysis* (6th ed.). Prentice-Hall International, New Jersey, USA.

Hand, B. (1989). Student understandings of acids and bases: a two year study. *Research in Science Education*, *19*(1), 133-144.

Hazer, B. (1995). *Genel kimya (General chemistry) (Third Edition)*. Karadeniz Teknik Üniversitesi Basımevi, Trabzon, Turkey (In Turkish).

Hofstein, A., & Kesner, M. (2006). Industrial chemistry and school chemistry: Making chemistry studies more relevant. *International Journal of Science Education*, *28*(9), 1017-1039.

Kala, N., Yaman, F., & Ayas, A. (2013). The effectiveness of predict–observe–explain technique in probing students' understanding about acid–base chemistry: A case for the concepts of pH, pOH, and strength. *International Journal of Science and Mathematics Education*, *11*, 555-574.

Karslı, F. & Çalık, M. (2012). Can freshman science student teachers' alternative conceptions of 'electrochemical cells' be fully diminished? *Asian Journal of Chemistry*, *24*(2), 485-491.

Kılavuz, Y. (2005). *The effects of 5E learning cycle model based on constructivist theory on tenth grade students' understanding of acid-base concepts* (Unpublished master thesis). Middle East Technical University, Ankara, Turkey.

King, D. (2012). New perspectives on context-based chemistry education: Using a dialectical sociocultural approach to view teaching and learning. *Studies in Science Education*, *48*(1), 51-87.

Kıyıcı, G. & Yumuşak, A. (2005). Fen bilgisi laboratuarı dersinde bilgisayar destekli etkinliklerin öğrenci kazanımları üzerine etkisi: Asit-baz kavramları ve titrasyon konusu örneği (The effects of computer assisted activity at science laboratory lesson on student's acquiry; example of acid – base concept's and titration topic). *The Turkish Online Journal of Educational Technology, 4*(4), 130-134 (In Turkish).

Kolomuç, A. & Çalık, M. (2012). A comparison of chemistry teachers' and grade 11 students' alternative conceptions of 'rate of reaction', *Journal of Baltic Science Education*, *11*(4), 333-346.

Kurnaz, M. A., & Çalık, M. (2008). Using different conceptual change methods embedded within 5E model: A sample teaching for heat and temperature. *Journal of Physics Teacher Education Online*, *5*(1), 3-10.

Lakatos, I. (1970). *Falsification and the methodology of scientific research programmes*. Cited by: Lakatos, I. ve Musgrave, A. (Eds.), Criticism and the growth of knowledge. Cambridge University Press, Cambridge, UK.

Marks, R., Bertram, S., & Eilks, I. (2008). Learning chemistry and beyond with a lesson plan onpotato crisps, which follows a socio-critical and problem-oriented approach to chemistry lessons – a case study*. Chemistry Education Research and Practice*, *9*, 267-276.

Merriam, S.B. (1988). *Case study research in education*. Jossey-Bass, San Francisco, USA.

Morgil, İ., Yavuz, S., Oskay, Ö. Ö. & Arda, S. (2005). Traditional and computer-assisted learning in teaching acids and bases. *Chemistry Education Research and Practice, 6*(1), 52-63.

Nakhleh M. B., & Krajcik J. S. (1994). Influence of levels of information as presented by different technologies on students understanding of acid, base, and pH concepts. *Journal of Research in Science Teaching*, *31*(10), 1077-1096.

Novak, D. J. (1988). Learning science and the science of learning. *Studies in Science Education*, *15*(1), 77-101.

Outertatani, L., Dumon, A., Trabelsi, M. A. & Soudani, M. (2007). Acids and bases: The appropriation of the Arrhenius model by Tunisian grade 10 students. *International Journal of Science and Mathematics Education, 5*, 483-506.

Oversby, J. (2000). Is it a weak acid or a weakly acidic solution*? School Science Review*, *81*(297), 89-91.

Özmen, H. (2003). Kimya öğretmen adaylarinin asit ve baz kavramlariyla ilgili bilgilerini günlük olaylarla ilişkilendirebilme düzeyleri (Chemistry student teachers' levels of linking their knowledge with daily life about acid and base concepts). *Journal of Kastamonu Faculty of Education*, *11*(2), 317-324 (In Turkish).

Özmen, H., Demircioğlu, G., Burhan, Y., Naseriazar, A. & Demircioğlu, H. (2012). Using laboratory activities enhanced with concept cartoons to support progression in students' understanding of acid-base concepts. *Asia-Pacific Forum on Science Learning and Teaching, 13*(1), Article 8.

Özmen, H., Demircioğlu, G., & Coll, R. K. (2009). A comparative study of the effects of a concept mapping enhanced laboratory experience on Turkish high school students' understanding of acid-base chemistry. *International Journal of Science and Mathematics Education*, *7*(1), 1-24.

Özmen, H. & Yıldırım, N. (2005). Çalışma yapraklarının öğrenci başarısına etkisi: Asit ve bazlar örneği (The effect of worksheet on student achievement: A case of acids-bases). *Türk Fen Eğitimi Dergisi, 2*(2), 124-143 (In Turkish).

Özsevgeç, T. (2007). *İlköğretim 5. sınıf kuvvet ve hareket ünitesine yönelik 5E modeline göre geliştirilen rehber materyallerin etkililiklerinin belirlenmesi (Determining effectiveness of guided materials about force and motion unit based on the 5E model for elementary students)* (Unpublished doctoral dissertation). Karadeniz Technical University, Trabzon, Turkey (In Turkish).

Pabuccu, A. (2008). *Improving 11th grade students' understanding of acid-base concepts by using 5E learning cycle model* (Unpublished doctoral dissertation). Middle East Technical University, Ankara.

Parchmann, I., Gräsel, C., Baer, A., Nentwig, P., Demuth, R., Ralled, B., & the ChiK Project Group. (2006). "Chemie im kontext": A symbiotic ımplementation of a context-based teaching and learning approach. *International Journal of Science Education*, *28*(9), 1041-1062.

Petrucci, R. H. (1989). *General chemistry principles and modern applications* (Fifth Edition). Macmillan Publishing Company, New Jersey, USA.

Pfundt, H., & Duit, R. (2000). *Bibliography: Student's alternative frameworks and science education* (5th ed.). University of Kiel, Kiel, Germany.

Pinarbasi, T., Sozbilir, M. & Canpolat, N. (2009). Prospective chemistry teachers' misconceptions about colligative properties: boiling point elevation and freezing point depression. *Chemistry Education: Research and Practice*, *10*, 273–280

Ross, B., & Munby, H. (1991). Concept mapping and misconceptions: A study of high-school students' understandings of acids and bases. *International Journal of Science Education*, *13*(1), 11-23.

Saka, A. Z. (2011). Investigation of student-centered teaching applications of physics student teachers. *Eurasian Journal of Physics and Chemistry Education*, *Special Issue*, 51-58.

Schwartz, A. T. (2006). Contextualized chemistry education: The American experience. *International Journal of Science Education*, *28*(9), 977–998.

Sisovic, D., & Bojovic, S. (2000). Approaching the concepts of acids and bases by cooperative learning. *Chemistry Education: Research and Practice*, *1*(2), 263-275.

Souders, J. (1999, July 9). *Contextually based learning: Fad or proven practice*. American Youth Policy Forum, Capitol Hill, Washington DC, USA.

Stolk, M. J., Bulte, A. M. W., de Jong, O., & Pilot, A. (2009a). Towards a framework for a professional development programme: Empowering teachers for context-based chemistry education. *Chemistry Education: Research and Practice*, *10*(2), 164-175.

Stolk, M. J., Bulte, A. M. W., de Jong, O., & Pilot, A. (2009b). Strategies for a professional development programme: Empowering teachers for context-based chemistry education. *Chemistry Education: Research and Practice*, *10*(2), 154–163.

Sunger, M. (2007). *An analysıs of efficacy beliefs, epistemology beiefs and attitudes towards science in preservice elementary science teachers and secondary science teachers* (Unpublished master thesis). Middle East Technical University, Ankara, Turkey.

Sutman, F., & Bruce, M. (1992). Chemistry in the community – chemcom. *Journal of Chemical Education*, *69*(7), 564–567.

Tamer, P. İ. (2006). *Effect of conceptual change texts accompanied with analogies on promoting conceptual change in acid and base concepts*. Unpublished PhD Thesis, Middle East Technical University, Ankara.

Toplis, R. (1998). Ideas about acids and alkalis. *School Science Review, 80*(291), 67-70.

Üce, M., & Sarıçayır, H. (2002). Üniversite 1. sınıf genel kimya dersinde asit-baz konusunun öğretiminde kavramsal değişim metinleri ve kavram haritalarının kullanılması (Using conceptual changing test and concept maps to teach the subject of acid bases in general chemistry course for freshmen classes). *Marmara University Atatürk Faculty of Education Journal of Educational Sciences*, *16*, 163-170 (In Turkish).

Ültay, N., & Çalık, M. (2011a). Asitler ve bazlar konusu ile ilgili örnekler üzerinden 5E modelini ve REACT stratejisini ayırt etmek (Distinguishing 5E model from REACT strategy: An example of 'acids and bases' topic). *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education, 5*(2), 199-220 (In Turkish).

Ültay, N., & Çalık, M. (2011b). *Kimya tutum ve deneyimleri anketinin türkçeye uyarlanması (Adaptation of chemistry attitude and experiences questionnaire into Turkish)*. Paper presented at Second National Chemistry Education Symposium, July 5-8, Atatürk University, Erzurum (In Turkish).

Ültay, N., & Çalık, M. (2012). A thematic review of studies into the effectiveness of context-based chemistry curricula. *Journal of Science Education and Technology, 21*(6), 686-701.

Ültay, N., Durukan, Ü.G. & Ültay, E. (2015). Evaluation of the effectiveness of conceptual change texts in the REACT strategy. *Chemistry Education: Research and Practice, 16*(1), 22-38.

Wilson, J. M. (1998). Differences in knowledge networks about acids and bases of year-12, undergraduate and postgraduate chemistry students. *Research in Science Education, 28*(4), 429-446.

Yager R. E., & Weld J. D. (1999). Scope, sequence and co-ordination: The Iowa project, a national reform effort in the USA. *International Journal of Science Education*, *21*(2), 169-194.

Yaman, F., Demircioğlu, G. & Ayas, A. (2006). *Yapılandırmacı öğrenme kuramına dayalı geliştirilen etkinliklerin öğrencilerin asit ve baz kavramlarını anlamaları üzerine etkileri (The efffect of activities developed in regard to constructivist learning theory on students' conceptions of acid-base concepts).* Paper presented at Seventh National Science and Mathematics Education Congress, Gazi University, September 7-9, Ankara (In Turkish).

Yıldız, V. G., Yıldırım, A. & İlhan, N. (2006). *Üniversite kimya öğrencilerinin asitler ve bazlar hakkındaki bilgilerini günlük hayatla ilişkilendirebilme düzeyleri (*Chemistry student teachers' levels of linking their knowledge with daily life about acid and base concepts). Paper presented at Seventh National Science and Mathematics Education Congress, Gazi University, September 7-9, Ankara (In Turkish)

Yin, R.K. (1994). *Case study research: Design and methods*. Sage, Thousand Oaks, CA, USA.

Zhang, L. (2014). A meta-analysis method to advance design of technology-based learning tool: Combining qualitative and quantitative research to understand learning in relation to different technology features. *Journal of Science Education and Technology*, *23*(1), 145-159.

◈◇◈

Appendix 1. A thematic review of acid-base studies

Studies	Purpose	Sample	Data Collection Instrument	Conclusion
Hand (1989)	To determine physics, chemistry and biology students' conceptual understanding of acids-bases	10^{th} grade students	Interview and concept test	Students understood the difference between concentration and strength of the acid. The chemistry students performed better than physics and biology students.
Botton (1995)	To enhance student understanding of acids-bases using collaborative concept mapping**.**	9^{th} grade students	Concept map	Students not only found concept mapping more secure but also their attitudes towards chemistry changed positively.
Bradley and Mosimege (1998)	To investigate student teachers' alternative conceptions of acids and bases.	Undergraduate students/ student teachers	A questionnaire with multiple-choice and discussion questions	Student teachers had more alternative conceptions of acids-bases than the students in natural sciences.
Toplis (1998)	To identify students' (alternative) conceptions of acids and bases.	8^{th} grade students	Interview and observation	The teaching intervention afforded the students to grasp *'indicator'* concept but they had still some difficulties of the acids and bases concepts.
Wilson (1998)	To investigate the representations of conceptual knowledge about acids and bases in three different levels.	12^{th} grade students, undergraduate chemistry students, graduate chemistry students	Concept map	An increase in student level enhanced the organization and differentiation of 'acids-bases' knowledge.
Sisovic and Bojovic (2000)	To identify effectiveness of cooperative learning method of acids-bases concepts.	9^{th} grade students	Worksheets, experiment reports, homeworks and quizzes	Students exposed to cooperative learning method were more successful in understanding the acids-bases concepts.
Oversby (2000)	To investigate the causes and possible solutions of students' confusion about acidity and pH concepts.	7^{th} grade students	Observation	Students confused acidity and pH concepts. Also, they did not know that a strong acid could have formed a weak acidic solution.
Üce and Sarıçayır (2002)	To examine the effect of conceptual change texts and concept maps on students' achievement on acids-bases topic and attitudes towards chemistry.	Freshman elementary student teachers	Concept-achievement test, attitude scale, logical thinking ability test	Conceptual change texts and concept maps were effective in increasing students' achievement, but had no effect on their attitudes towards chemistry.
Cho (2002)	To investigate the effect of in-service education on teachers' awareness of STS approach.	Science teachers	Constructivist learning environment survey and science education reform inventory	In-service education positively affected the teachers' awareness of STS approach.
Demircioğlu (2003)	To determine students' pre-existing knowledge and/or alternative conceptions and overcome them via 5Es learning model.	10^{th} grade students	Concept-achievement test, science process skills test, questionnaire and interview	The experimental group exposed to 5Es learning model outperformed the control group.
Erduran (2003)	To search matching and mismatching points of students' and teachers' knowledge of acids and bases.	7th grade students	Observation	Teachers' knowledge was based on the books whilst students' knowledge was constructed on their experiences of the acids and bases.
Özmen (2003)	To examine how the chemistry student teachers relate their acids and bases concepts with daily life.	Chemistry student teachers	Open ended questions	Students were unable to link their acids and bases concepts with daily life events at a satisfactory level.

Demircioğlu, Özmen and Ayas (2004)	To identify upper secondary school students' alternative conceptions of acids and bases.	10th grade students	Questionnaire with open ended and multiple choice questions	Students had a variety of alternative conceptions and limited conceptual understanding of acids-bases.
Morgil, Yavuz, Oskay and Arda (2005)	To determine the effect of computer assisted instruction on students' three dimensional spatial visualization abilities, computational attitudes and learning styles of acids and bases.	Chemistry student teachers	Achievement test, attitude scale, learning styles inventory and Purdue rotation-orientation test	The students at the experimental group performed better than those in the control group.
Feng and Tuan (2005)	To determine the effect of ARCS (Attention, Relevance, Confidence and Satisfaction) model on students' motivation and achievement in learning about acids and bases.	11th grade students	Motivation scale, interview and achievement test	The ARCS model positively affected the students' success and motivation.
Kılavuz (2005)	To determine the effects of 5Es learning model on student conceptual learning of acids and bases and their attitudes towards chemistry.	10th grade students	Achievement test, attitude scale and science process skills test	5Es learning model was more effective in increasing conceptual understanding than did the traditional method but attitudes towards chemistry showed equal development in both groups.
Çetingul and Geban (2005)	To examine the effect of conceptual change texts oriented instruction accompanied with analogies on upper secondary school students' conceptions about acids and bases.	10th grade students	Concept test	The students in the experimental group taking conceptual change oriented instruction performed much better than those in the control group exposed to traditional instruction
Kıyıcı and Yumuşak (2005)	To determine the effect of computer assisted materials about acid-base titration on students' gains.	Sophomore elementary student teachers	Achievement test	The students in the experimental group outperformed those in the control group.
Özmen and Yıldırım (2005)	To determine the effect of worksheets on students' achievement about acids and bases.	10th grade students	Achievement test	The students in experimental group were more successful in understanding the acids and bases concepts than those in the control group.
Bozkurt, Aydin, Yaman, Usak and Gezer (2005)	To identify students' views about greenhouse gas, ozone layer and acid rain.	6th, 7th and 8th grade students	Questionnaire	Students had limited knowledge about greenhouse gas, ozone layer and acid rain.
Bilgin and Yahşi (2006)	To examine the effect of different laboratory approaches on students' conceptual learning of acids and bases.	8th grade students	Concept test	Discussion sessions, which were held before and after experiments, were more effective in teaching the acids and bases concepts and in changing misconceptions.
Yaman, Demircioğlu and Ayas (2006)	To investigate the effectiveness of the teaching materials with 5Es learning model on student understanding of acids and bases topic.	10th grade students	Concept-achievement test and interview	The experimental group exposed to 5Es learning model outperformed the control group
Geban, Taşdelen and Kırbulut (2006)	To explore the effectiveness of conceptual change texts on remedying students' alternative conceptions about acids and bases.	10th grade students	Concept test and science process skills test	The students in the experimental group performed better than those in control group.
Yıldız, Yıldırım and İlhan (2006)	To examine how different sample groups relate their acids and bases concepts with daily life.	Chemistry, chemical engineering and chemistry students teachers	Questionnaire	Chemistry student teachers were more successful at relating acids and bases topic with daily life events.
Tamer (2006)	To determine the effect of conceptual change texts accompanied with analogies on student achievement of acids and bases and their attitudes towards chemistry.	10th grade students	Concept test, attitude scale, science process skills test and interview	The students in the experimental group performed better than those in control group.

Ouertatani, Dumon, Trabelsi, and Soudani (2007)	To identify Tunisian grade 10 students' knowledge of acids and bases	10th grade students	Paper and pencil tests	The assimilated knowledge is transitory. Furthermore, some alternative conceptions, which threaten the learning of Brønsted's model, appeared.
Ekmekçioğlu (2007)	To examine the effect of concept maps and meaningful learning theory on student achievement about acids and bases.	10th grade students	Scientific achievement test and attitude scale	The students in the experimental group exposed to concept maps and meaningful learning theory performed better than those in control group
Gokcek (2007)	To identify the effectiveness of the multiple intelligence activities on student achievement and attitude towards science.	8th grade students	Achievement test and attitude scale	The multiple intelligence activities increased student achievement and engendered positive attitudinal change.
Drechsler and Driel (2008)	To explore experienced teachers' pedagogical content knowledge of acids and bases topic.	Chemistry teachers	Interview	Although all teachers recognized some of the students' difficulties as confusion between models, only a few chose to emphasize the different models of acids and bases.
Pabuccu (2008)	To determine the effect of 5Es learning model on student conceptual understanding of acids and bases.	11th grade students	Concept test, attitude scale, science process skills test and nature of science survey	The students in the experimental group performed better than those in control group
Burhan (2008)	To determine the effect of worksheets enriched with concept cartoons on student conceptual understanding of acids and bases concepts.	8th grade students	Concept-achievement test, interview and worksheets	The worksheets enriched with concept cartoons facilitated and significantly increased students' conceptual understanding of the acids and bases topic.
Cokelez and Dumon (2009)	To compare Turkish and French students' ideas of acid and base concept.	11th and 12th grade students	Questionnaire with open ended and multiple choice questions	Turkish and French students tended to use different acid-base models. That is, to explain acid-base concept, French students employed Bronsted-Lowry theory whilst Turkish students deployed Arrhenius model.
Özmen, Demircioğlu and Coll (2009)	To identify the effect of concept mapping enhanced laboratory experience on Turkish high school students' understanding of acid-base chemistry.	10th grade students	Concept-achievement test	Concept mapping in conjunction with laboratory activities was more enjoyable, helped student link concepts, and reduced their alternative conceptions
Demircioğlu, Vural and Demircioğlu (2012)	To investigate the effect of REACT teaching material on gifted students' conceptions of acid-base neutralization concept	7th and 8th grade students	Word association test and questionnaire	REACT teaching material made a significant contribution to teach the neutralization concept
Özmen, Demircioğlu, Burhan, Naseriazari and Demircioğlu (2012)	To determine the impact of laboratory activities enriched with concept cartoons on student achievement of acid-base concepts.	8th grade students	Achievement test and interview	The laboratory activities enriched with concept cartoons increased student achievement and effectively overcome their alternative conceptions of the acid-base concepts.
Kala, Yaman and Ayas (2013)	To investigate the effectiveness of POE on students' conceptual understanding of acids and bases.	High school students	POE tasks and interview	POE tasks were effective in enhancing student understanding of acid and base concepts. However, students still had some alternative conceptions about pH and pOH.

Appendix 2. Chemistry attitudes and experiences questionnaire (CAEQ) (Adapted from Dalgethy, Coll and Jones, 2003, p.663)

The following information will be only used for demographic purposes. Please write down related information prior to answering the questionnaire.

Age: Gender: ( ) Male ( ) Female

This part of the questionnaire investigates the perceptions you have about chemistry and related topics. For example: If you feel chemistry is mostly about the study of natural substances, and only a little bit about the study of synthetic substances then you would answer the following questions as shown:

Chemistry Natural 1 2 (3) 4 5 6 7 Synthetic Substances

Please indicate what you think about the following			
		Chemists	
1	unfit	1 2 3 4 5 6 7	athletic
2	socially unaware	1 2 3 4 5 6 7	socially aware
3	environmentally unaware	1 2 3 4 5 6 7	environmentally aware
4	fixed in their ideas	1 2 3 4 5 6 7	flexible in their ideas
5	only care about their results	1 2 3 4 5 6 7	care about the effects of their results
6	unimaginative	1 2 3 4 5 6 7	imaginative
7	impatient	1 2 3 4 5 6 7	patient
		Chemistry research	
8	harms people	1 2 3 4 5 6 7	helps people
9	decreases quality of life	1 2 3 4 5 6 7	improves quality of life
10	creates problems		solves problems
11	causes society to decline	1 2 3 4 5 6 7	advances society
		Chemistry jobs	
12	repetitive	1 2 3 4 5 6 7	varied
13	boring	1 2 3 4 5 6 7	interesting
14	unsatisfying	1 2 3 4 5 6 7	satisfying
15	tedious	1 2 3 4 5 6 7	exciting

Appendix 3. An example teaching design for each group

Group	Step	Lecturer's Role	PSTs' Role
REACT	**Relating**	Handed "Acid Rain" reading text over to the students and asked some curious questions to activate PSTs' pre-existing knowledge, i.e. Have you ever seen or heard any acid rain phenomena in your closer environment?" "In view of the reading text, how can you describe 'pH, pOH, acid and base' concepts?	Carefully read the 'Acid rain' text and answered the questions using their pre-existing knowledge.
	Experiencing	Afforded the PSTs to engage in hands-on activities such as "Recognizing acids and bases" and "Measuring their pH values." Then she required the PSTs to draw a pH scale of the 'acid rain'. Promoted the PSTs to present their investigated topic of the acid-base chemistry and guided them if necessary.	Carried out the hands-on activities such as "Recognizing acids and bases" and "Measuring their pH values" and filled in the experiment sheet based on their observations. Also, they drew a pH scale of the 'acid rain'. Presented their investigated topic of the acid-base chemistry, e.g. acid-base theories--Arrhenius, Bronsted-Lowry and Lewis, conjugate acid-base pairs, acid-base reactions in acid rain, autoprotolysis of water.
	Applying	Handed a questionnaire covering acid-base definitions, conjugate acid-base pairs, acid-base reactions in acid rain and pH calculation out to the PSTs.	Individually solved the questionnaire and interactively discussed all items with the lecturer. Hence, they transferred their gained knowledge to novel issues.
	Cooperating	Called the PSTs for searching the question "What happens if pH value of blood increases or decreases?"	Searched and responded the research question within their small groups and presented their views within a whole-class discussion.
	Transferring	Launched some context-based questions, "What should we do when honey bee or wasp stings? Is there any relationship between these phenomena and the acid-base chemistry?" Later, she required the PSTs to find creative solutions for preventing/reducing the acid rain by taking into account lecturer-prepared concept network that summarizes the negative effects of acid rain.	Adapted their acid-and base chemistry knowledge into a new daily/novel phenomenon. Then, given the lecturer-prepared concept network, they developed some possible solutions of the acid rain for preventing/reducing its negative effects. Thus, they transferred newly structured knowledge into different issues.
5Es	**Engage**	Handed a sheet with acid rain pictures out to the PSTs and asked them for creating a story in their small groups. Aroused some questions to stimulate their pre-existing knowledge, i.e. "Do you have any idea about 'acid, base and acid rain' concepts?"	Created the acid rain story in their small groups. Later, spokesman of each group read the story aloud to their peers. They answered the questions via their pre-existing knowledge.
	Explore	Enabled the PSTs to engage in hands-on activities, e.g. "Let's identify acids and bases" that covers 'acid, base, pH and pOH' concepts.	Implemented the hands-on activities, e.g. "Let's identify acids and bases" and filled in the experiment report within their small groups in regard to their observations.
	Explain	Didactically explained Arrhenius, Bronsted-Lowry and Lewis acid-base theories, the conjugate acid-base pairs, reactions in acid rain and autoprotolysis of water.	Carefully listened lecturer's explanations and took notes if necessary.
	Elaborate	Engaged the PSTs in hands-on POE activities, e.g. "Determining acid-base strengths by electrical conductivity."	Conducted the hands-on POE activities, e.g. "Determining acid-base strengths by electrical conductivity" and improved their knowledge and/or remedied their alternative conceptions of the acid-base chemistry topic through a whole-class discussion.
	Evaluate	Required the PSTs to write down what they had learned in these classes and handed over an acid-base diagnostic tree to evaluate their gained knowledge of the 'acid-base' concepts.	Put down what they had learned in these classes and filled in the acid-base diagnostic tree.

Control	**Attention and motivation**	Asked the PSTs to give 'acid-base' examples from daily life.	Gave the acid-base examples from daily life by help of their pre-existing knowledge.
	Explanation	Didactically addressed the acid-base theories--Arrhenius, Bronsted-Lowry and Lewis—and autoprotolysis of water and then casted some questions about the topic.	Responded the questions and then interactively discussed some of the concepts through a whole-class discussion.
	Individual learning activities	Illustrated how to solve pH calculation questions on the board and clarified any unclear point asked by the PSTs. Asked some procedural questions to the PSTs and made explanations if necessary. For example, what is pH of solutions with each of the following $[H^{+}]$? (a) 1.0×10^{-12} (b) 5.3×10^{-10} (c) 6.6×10^{-2}	Carefully observed the procedural problem solving strategy, and took notes and asked any unclear point. Volunteer PSTs solved the procedural questions on the board.
	Evaluation	Asked several questions covering the whole topic, e.g. Please classify each of the species as an acid or a base at the given conjugate acid-base reactions; a) $HOBr_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^{+}_{(aq)} + OBr^{-}_{(aq)}$ b) $H_2CO_{3\,(aq)} + 2H_2O_{(l)} \rightleftharpoons H_3O^{+}_{(aq)} + HCO_3^{-}{}_{(aq)}$ c) $HNO^{-}_{3(aq)} + HPO^{-2}_{4(aq)} \rightleftharpoons NO^{-}_{3\,(aq)} + H_2PO^{-2}_{4(aq)}$ d) $HSO^{-}_{3(aq)} + NH^{+}_{4(aq)} \rightleftharpoons NH_{3(aq)} + H_2SO_{3(aq)}$ e) $HS^{-}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_2S_{(aq)} + OH^{-}_{(aq)}$ f) $CH_3COOH_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^{+}_{(aq)} + CH_3COO^{-}_{(aq)}$	Volunteer PSTs come to the board and solved the questions.