The Effects of Scientific Inquiry-Based Instruction in Lectures on Students' Scientific Knowledge of Acid-base Chemistry

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Abstract: The purpose of this study was to develop lecturing materials based on scientific inquiry-based in lecture and investigate the effects of the developed lecturing materials on students' scientific knowledge of Acid-base Chemistry. The study involved 54 first year pre-service chemistry teacher from two classes of a basic chemistry course taught by different lecturers with equal teaching experience. One of the class was assigned to the control group (N=27) and was taught with traditional strategy, and the other class was assigned as experimental group (N=27) which received scientific inquiry-based materials in lectures. The Scientific Knowledge Test Instruments was used to collect data after the study as post-test. The results showed that the experimental group's score of scientific knowledge on Acid-base Chemistry (M = 15.8, SD = 2.83) was higher than the control group (M = 12.1, SD = 2.84) with a *d*-effect size of 1.31 (much larger than typical). T-test analysis yielded *t* (df = 26) = 5.218, p = 0.000 (two-tailed). This indicates that the implementation of the new lecturing material developed in this study strongly improves students' scientific knowledge of Acid-base Chemistry compare with traditional strategy.

Keywords: new lecturing material; scientific inquiry-based instruction in lectures; scientific knowledge; acid-base chemistry.

Acid-base concepts have become objects of science education research for a long time (Cros et al., 1986; Hand, 1989; Kind, 2004; Lin & Chiu, 2010; Bayrak, 2013; Damanhuri et al., 2016). At least, there are two crucial problems related to students' understanding of Acid-base Chemistry (Kind, 2004; Lin & Chiu, 2010; Artdej et al., 2010; Kala et al., 2013; Bayrak, 2013). The problems are students' misconception and unscientific students' mental model. Misconception or alternative conception is the most common problem of students' understanding on acid-base concepts. Several alternative conceptions on this topic have been uncovered by some researchers, e.g. Neutralization is the division of an acid or something becoming different from an acid (Kind, 2004); there is neither H^+ nor OH^- ions in the resulting solutions at the end of all neutralization reactions (Demircioglu, 2009); more bubbles produced by a strong acid upon reaction with metal than a weak acid (Artdej et al., 2010); pH was a represent of the solution acidity, while pOH was a measurement of the solution basicity (Kala et al., 2013); and compound containing OH group likes CH_3COOH is a base (Bayrak, 2013).

In light of mental model, Lin & Chiu (2007; 2010) found out four students' mental model for acid-base concepts, i.e. the scientific model which based on Arrhenius Model, the Phenomenon Model which based on macroscopic characteristics, the Character-Symbol Model which based on names of functional groups of substance, and the Inference Model which based on inference of characteristics. Resembling to these finding, most of the students also had poor understanding to draw weak and strong acids (Kala et al., 2013).

Worksheets Developed to Improve Instructional Affectivity

Some of the instructional strategies have been developed to reduce instructional problems of Acid-base Chemistry (Bilgin, 2009; Demircioglu et al., 2005; Demircioglu, 2009; Ozmen et al., 2009; Rahayu et.al., 2011; Kala et al., 2012; Georgiou and Sharma, 2015; Gordon et al., 2015; Julien and Lexis, 2015; Naiker and Wakeling, 2015; Wegener et al., 2015; Williamson et al., 2015). However, problems related to students' understanding on Acid-base Chemistry have not been solved completely. Needs assessment of basic chemistry instruction showed that most of university students applied the low level of cognitive skills and learned by rote learning (Muntholib et al., 2014). This condition to be a challenge for educators to develop instructional strategies can be used to improve students' cognitive skills and knowledge and to reduce students' alternative concepts. Some diagnostic tests can be used to measure the change in students' conceptions has also been developed (Wattanakasiwich et al., 2013; Tongchai et al, 2009). This research focuses on developing new lecturing materials based on scientific inquiry using in lecture to improve to the students' scientific knowledge of Acid-base Chemistry.

In the context of Indonesian Education, starting from 2013 the government has implemented new curriculum (Curriculum 2013) for elementary and secondary education. The curriculum emphasizes on three kinds of learning outcomes namely: attitudes both social and spiritual, scientific knowledge, and skills (Minister of Education and Culture Republic of Indonesia Regulation Number 59 the year 2014). The skills in this regulation mean scientific processes or scientific inquiry or scientific methods and instruction that applied this skills is called as the scientific approach. The Scientific approach consists of five learning experiences namely observing, questioning, experimenting, associating, and communicating. As a consequence, every competence standard or performance expectation in Indonesian curriculum consist of two kinds of competency, scientific (content) knowledge and scientific inquiry skill competencies.

The main problem in implementing scientific inquiry-based curriculum is the low of pre- and in-service teacher's competencies to do scientific inquiry (Lustick, 2009; Dudu & Vhurumuku, 2012; Capps & Crawford, 2013). Lustick (2009) reported the failure of a project conducted to help teacher candidates (master's program) acquire the skills, knowledge, and dispositions necessary to foster learning through inquiry. Dudu & Vhurumuku (2012) revealed that teachers varied considerably in how they attempted to engage learners in the active search for knowledge, from structured methods of close-ended inquiry to some form of open-ended inquiry. Capps & Crawford (2013) showed that the majority of teachers held limited views of inquiry-based instruction. The views were reflected in the teacher's teaching practice. More than half of teachers doing the teaching practice did not reveal elements of inquiry including understandings of essential features of and abilities to do scientific inquiry. Our preliminary survey showed that prospective-teachers' understanding on scientific inquiry did not meet our expectations. This evidence suggests that teachers preparation that hat are expected to apply scientific inquiry approach in their teaching practices are not easy and should be started from universities' teaching-learning processes.

The School Scientific Inquiry

The term inquiry refers to at least three distinct categories of activity (Minner et al., 2010), i.e. pure, classroom, and pedagogical scientific inquiry. Pure scientific inquiry (SI) or what scientists do refers to the characteristics of the process through which scientific knowledge is developed, including the conventions involved in the development, acceptance, and utility of scientific knowledge (Schwartz et al., 2004). The second classification is cclassroom scientific inquiry or how students learn talks about activities conducting by students in order to inquire knowledge and skills through thinking and doing on a phenomenon or problem, often mirroring the processes used by scientists. The last division of scientific inquiry, pedagogical scientific inquiry, looks up the teachers' activities in order to facilitate students for doing investigations. However, whether it is the scientist, student, or teacher who is doing or supporting inquiry, the act itself has some core components. The NRC (1996; 2000) in National Science Education Standards (NSES) described these core components from the learner's perspective as "five essential features of classroom inquiry" as follows:

1) Learners are engaged by scientifically oriented questions.
2) Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
3) Learners formulate explanations from evidence to address scientifically oriented questions.
4) Learners evaluate their explanations according to alternative explanations, particularly those reflecting scientific understanding.
5) Learners communicate and justify their proposed explanations.

Inquiry and the Scientific Approach

Curriculum 2013 applied in all levels of Indonesian school uses the scientific approach as the official instruction. The scientific approach comprises five learning experiences namely observing, questioning, experimenting, associating, and communicating. Each learning experience provides students with opportunities to construct understanding within the context of their experiences consistent with science as inquiry. Table 1 depicts teaching-learning activities of scientific approach learning experiences of official Indonesian curriculum.

Table 1 Teaching-learning Activities of Scientific Approach of Official Indonesian School Curriculum (Modified from Regulation of Indonesian Minister of Education and Culture Number 59 the year 2014)

Learning Experiences of Scientific Approach	**Teaching-learning Activities**
Observing	• Observe or read or hear initial phenomenon(a) to emerge question(s).
Questioning	• Constructs, identify, and asks questions such as, "Why did this happen?" "What kind of matter could show the phenomenon?" Shows interest in the topic. • Formulate hypotheses.
Experimenting	• Designs and conducts an experiment or other way to collect data or evidences. • Analyze and interpret data and draw conclusions.
Associating	• Develops meaning to the evidence or conclusions and formulate explanations from them. • Discuss and evaluate explanations based on scientific criteria and current knowledge. • Develops law or mathematical formula and solves problems.
Communicating	• Constructs any form of representation or media for presenting data, evidence, or conclusions. • Forms reasonable and logical argument to communicate explanations. • Demonstrate problems solving. • Listens critically to others' explanations • Checks for understanding among peers

Purpose of the Study

The evidence for the effectiveness of inquiry-based instruction is conclusive. The experiment conducted by Wilson et al. (2010) showed that students in the inquiry-based class got significantly higher levels of scientific knowledge than students experiencing commonplace (direct) instruction, both assessments performed immediately following the instruction or conducted four weeks later. Unfortunately, inquiry models developed in the previous study were not fully compliant with the basic chemistry curriculum in university. In university, the contents of a science or a branch of science were divided into two courses, the science itself (theoretical course) and laboratory work of the science. Basic chemistry contents, for instance, are broken down into two courses, basic chemistry (theoretical course) and laboratory work of basic chemistry (experimental course). Basic Chemistry Course emphasizes understanding of chemistry concepts and theories and is usually given using lecturing method. Laboratory Work of Basic Chemistry Course underlines laboratory motoric skills by confirming concepts gained in the theoretical course. This separation can lead to loss of scientific inquiry understanding and competencies to do scientific inquiry from intended learning outcomes of science instruction. Therefore, the learning outcomes of scientific inquiry understanding and competency to do scientific inquiry should be defined explicitly prior to basic chemistry and laboratory work of basic chemistry instruction. This research explicitly defines the learning outcome of scientific inquiry understanding to prior to Basic Chemistry instruction. Learning experience of "experimenting or doing the investigation” of the official scientific approach of Indonesian school scientific inquiry (Minister of Education and Culture Republic of Indonesia Regulation Number 59 the year 2014) or “gives priority to evidence” in five essential features of school scientific inquiry (NRC, 2000) was dropped. Instead, we provide experimental data from secondary sources and the scientific inquiry-based instruction developed in this research is called as scientific inquiry-based instruction in lecture. Nevertheless, we only investigate the ipact of implementation of this instructional strategy to the students’ scientific knowledge. As a comparison, we used traditional or direct instruction strategy as the control. Therefore, the research question addressed in this research is:

> Would the scientific inquiry-based instruction in lecture or traditional instruction strategies be more effective in improving university students’ scientific knowledge about the chemistry of acid-base contents?

METHODS

Research Design

The study utilized a posttest only quasi-experiment design (Creswell, 2012). We were unable to assign the students randomly to the experimental or control groups due to the constraint of the context in which students’ distribution to the groups ruled by institution. Independent variables of the research are two kinds of instructional strategy namely scientific inquiry-based instruction in lecture (X) and traditional instruction (Y). The dependent variable of the research is students' scientific knowledge on acid-base chemistry.

Subjects, Participants, Course, and Program

The subjects for this study were fifty-four of first-year university students from Study Program of Chemistry Education State University of Malang. Two lecturers, each of which had one class, participated in the study. One of the lecturer and his class was assigned to the experimental group, while the other lecturer and his class became the control group. Both of lecturers had 21 years of lecturing experience with various kinds of instructional approach and strategies. From this, we can say that those lecturers had the similar experience in teaching chemistry.

The basic chemistry contents in the Chemistry Education Program, State University of Malang, is divided into two courses, basic chemistry itself (theory) and laboratory work of basic chemistry subjects. The basic chemistry subject consists of four 50-minute periods per week. The lecturer conduct lectures in the classroom set without experimental aids, usually using chalk and talk and power point only. The main goal of the basic chemistry course understands the basic concepts of chemistry as a foundation for studying advanced chemistry concepts (Department of Chemistry, State University of Malang, 2014).

The Scientific Inquiry-Based Instruction in Lecture Material

The scientific inquiry-based instruction in lecture material was designed to help students to: a) construct question based on confirmed prior knowledge and limited experimental data, b) analyse given data, look for correlation among variables, and make conclusion, c) make interpretation and give explanation to the conclusion, and deep understanding, d) correlate to other concepts and mathematic implication, e) communicate in the group or classical discussion and evaluation, f) reflect what they have studied, what difficulty they have met, and what they have to do to be better, and g) independent practise (drill) and confirmation feedback of their work.

To develop such material, we examined a number of related resources such as the Indonesian Curriculum for Senior High School Chemistry Subject, Undergraduate Chemistry Education Program Curriculum, and chemistry's teacher lesson plan for Chemistry of Acid-base Topic, and classroom observation of teaching and learning processes. Based on these examinations, we developed a worksheet for six instructional processes aiming to construct an understanding of acid-base chemistry concepts and scientific inquiry. One of the worksheets used in this study is shown in Table 2. As can be seen from the table, each worksheet consists of three sections. They are an introduction that consists of confirmation of prior and prerequisite knowledge and remembering students to scientific inquiry; instructional processes using scientific inquiry-based instruction in lecture strategy; and closure. The scientific inquiry-based instruction in lecture material was first piloted to the first year of chemistry education class consisting of thirty-three students. During the pilot study, we carried out classroom observation, informal students' interview, and tests. Based on the result of the pilot study, the scientific inquiry-based instruction in lecture material was revised and used in this study.

Table 2 Example of a worksheet used in experimental group, Scientific Inquiry-based Instruction in Lecture

<table>
<tr><td colspan="3">Introduction:
Confirmation of students' understanding on acids, bases, and salts: (1) Salts are formed when neutralization reaction is occurred, (2) Acids, bases, and salts undergo dissociation if dissolved in water to be their ions, and (3) In their solution, salts, and strong acid-base undergo completely dissociation, while weak acid-base undergo partially dissociation.</td></tr>
<tr><td colspan="3">Main Activities:</td></tr>
<tr><td>Scientific Inquiry Skills:</td><td>Scientific Knowledge:</td><td>Teaching-learning Activities:</td></tr>
<tr><td>• Construct and ask questions</td><td>Salt solution can be acid, neutral, or base.</td><td>Students are shown data that ammonium chloride solution is acid, sodium chloride solution is neutral, and sodium bicarbonate solution is base.</td></tr>
</table>

		Students are guided to construct and ask questions such as: (1) Why can salt solution be acid, neutral, or base? (2) What kind of salt does produce acid solution?
• Analyse data and draw conclusion.	All salts produced by neutralization reaction of strong acid and weak base are acid.	Students are given data about salts in which their solutions are acid. Students are guided to analyse data and draw conclusion that all salts produced by neutralization reaction of strong acid and weak base are acid.
• Interpret and draw explanation to the conclusion, and deep understanding.	Cation of a salt mirrors properties of the base from which it comes, while the anion of a salt shows properties of the acid from which it is originated.	Students are guided to connect properties of salt solutions and properties of acids and bases from which the salt come to show that acidity or basicity of a salt solution related to acid or base from which it is originated.
• Correlate to other concepts and mathematic implication.	K_a = $[H^+]$[anion of a weak acid] K_b = [OH-][cation of a weak base] $K_w = K_a$ X K_b	Students are guided to understand that hydrolysis of anion of week acid (or cation of week base) produces week acid, anion of the week acid, and OH^- (decreasing concentration of H^+ ion). The species of week acid, anion of the week acid, and H^+ ion in a solution will form an equilibrium with constant K_a. Students are guided to correlate K_a or K_b of an acid or a base in a hydrolyzed slat to K_w.
• Communicate in the groups or classical discussion and evaluation.	-	Students are guided to communicate and justify the explanations and conduct argumentation.
Closure: Summary; Students' reflection on what they have studied, what difficulty they have met, and what they have to do to be better; and independent practice (drill) and confirmation feedback of their work.		

Teaching Intervention

Both experimental and control group lecturers were invited to a meeting before conducting research to understand the goal of the research, the treatment for the experimental group as well as control group, and the essential difference between the two. The researchers also held meetings as often as necessary to correct any misuse of the scientific inquiry-based instruction in lecture as a teaching strategy. Both experimental and control groups were observed during the implementation of lecturing strategies. In a typical instructional sequence, while the experimental lecturer tried to help students analyze data and evidence, draw conclusions, interpret and explain conclusions, and construct the reasonable and logical argument, the control group lecturer used a lecturer-centered approach mainly involving talk and chalk sessions.

The two groups spent equal time studying the chemistry of acid-base. However, the lesson in the experimental group focused on the prepared worksheets that represents the scientific inquiry-based instruction in lecture materials and were designed to develop cognitive skills and students' understanding on acid-base concepts. As an example, the implementation procedure of one of the worksheets is described below:

The first stage of each worksheet was addressed to check students' prior knowledge and misconceptions (Table 2) which were assessed by the teacher as well as the constructed pre-requisites needed for learning the coming up lesson. This was used at the start of the lesson to prepare students as they are ready to learn.

The second stage of each worksheet was addressed to develop students' scientific knowledge using scientific inquiry skills i.e.: construct and ask questions; analyze data and draw conclusion; interpret and draw explanation to the conclusion, and deepen the understanding; correlate to other concepts and mathematic implication; and communicate in the group or classical discussion and evaluation. The lecturer's role in the teaching-learning activities was as guidance.

The third stage of each worksheet was addressed to make an overview of scientific inquiry and scientific knowledge in the form of the summary. In addition, in this stage students were asked to reflect what difficulty they have encounter in the teaching-learning process and what they have to do to increase their understanding on scientific inquiry and scientific knowledge. To reinforce understanding, students also received independent practice (drill) and confirmation feedback on their work.

Instruments

Thirty-two items of multiple-choice test related to the scientific knowledge were constructed for the purpose of assessing students' understanding on acid-base concepts. Each item involved one scientifically acceptable answer and four reasonable and plausible distracters, including common misconception revealed in previous studies. During the development of the instrument, the following steps were taken into consideration. First, instructional objectives of Acid-base Chemistry were determined. Second, the literature related to Acid-base Chemistry and students' misconception on acid-base concepts was reviewed. And then, the result of the review was used to develop the multiple-choice items of scientific knowledge of acid-base chemistry. One example of items used in this instrument is shown in Table 3.

Table 3. An example of problems used in the instrument

8.	Aqueous solutions of $HClO_3$,$HClO_4$, H_2SO_3, H_2SO_4,and H_3PO_4have the same concentration (Ar P = 15; S = 16; Cl = 17). Which one has the highest first ionization degree?	
	A. $HClO_3$(*aq*)	D. H_2SO_4(*aq*)
	B. $HClO_4$(*aq*)	E. H_3PO_4(*aq*)
	C. H_2SO_3(*aq*)	

The correct answer of this problem is option B. The common misconception in this problem is that "the number of hydrogen atoms in a substance indicates the strength of an acid".

For the purposes of content validation and reduction of errors, the instrument was examined by a group of experts consisting of three chemistry lecturers who had experience for over twenty years at The Faculty of Mathematics and Science State University of Malang. These experts checked the fidelity of the scientific knowledge and determined the acceptable correct choice for each item of the instrument. In addition, the instrument was piloted to ninety first-year students from Faculty of Mathematics and the Science State University of Malang who were taking Basic Chemistry Subject. For the reliability of the instrument, an analysis was made producing 25 items (elected from 32 items on the initial instrument) as a final instrument of students' scientific knowledge of Acid-base Chemistry (the final instrument is enclosed herewith). The alpha reliability coefficient (KR20) of the final instrument was 0.762 (r_{-table} = 0.2; status = reliable; degree = high). Students completed this instrument in a 75 minutes period.

RESULTS AND DISCUSSION

The instrument of students' scientific knowledge of Acid-base Chemistry was administered to both the experimental and control group students after the instruction.

Homogeneity of the experimental and control groups were determined using students' final test score of General Chemistry I subject of the previous semester. No statistically significant mean difference was found between the two groups with respect to the General Chemistry I final test score *t* (df = 26) = 0.493, p = 0.626 (two-tailed), indicating that students in the experimental and control groups were similar in respect of the variable. As there were no significant differences between the experimental and the control groups on the General Chemistry I final test score, the post-tests scores of the groups could be compared using an independent *t-test*.

The question of the research is whether the scientific inquiry-based instruction in lecture material or traditional instruction will be more effective in improving university students' scientific knowledge on Chemistry of Acids and Bases. The data showed that university students' scientific knowledge on the chemistry of acid-base of the experimental group (M = 15.8, SD = 2.83) was higher than the control group (M = 12.1, SD = 2.84). Table 4 shows that t-test analysis using SPSS program yielded *t* (df = 26) = 5.218, p = 0.000 (two-tailed). It suggests that the means difference between a pair of data sets are statistically significant. In another word, the scientific inquiry-based instruction in lecture implemented in this research is more effective in improving university students' scientific knowledge on the chemistry of acid-base than the traditional instruction one.

Table 4. Paired Sample Tests of the Experimental and Control Groups in Scientific Knowledge

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Experimental group - Control Group	3.70370	3.68797	.70975	2.24479	5.16262	5.218	26	.000

This study found that students receiving scientific inquiry-based instruction in lecture reached significantly higher levels of scientific knowledge than those experiencing traditional or direct instruction. A reason for this is that the scientific inquiry-based instruction in lecture is appropriate to acid-base concepts. As described before, Scientific Inquiry-Based Instruction in lecture material emphasizes reasoning and connecting that relate one concept to another. Also, Acid-base Chemistry related to many other chemistry concepts, such as the particulate nature of matter, electrolyte, oxidation and reduction, and chemical equilibrium. This study therefore contributes to the growing body of evidence demonstrating the effectiveness of inquiry-based instruction and supports the advocacy for inquiry-based instruction stated in national and international science education documents (NRC, 1996, 2000, 2012; Ministry of Education and Culture Republic of Indonesia, 2013). The finding from this study is similar to the findings by Wilson et al. (2010), especially the scientific knowledge learning goal.

The scientific inquiry-based instruction in lecture is the instruction strategy that exploits scientific inquiry method to build students' understanding on science (scientific knowledge, scientific inquiry competencies, and nature of science) without using laboratory facilities. The main difference between the scientific inquiry in lecture and real classroom scientific inquiry reside in learning experience of "give priority to evidence" in five essential features of school scientific inquiry (NRC, 2000) or "experimenting" in the scientific approach (Ministry of Education and Culture Republic of Indonesia, 2013), especially data collection step. In the scientific inquiry in lecture, data are collected from secondary resources like textbooks, reports and journals, and sometimes demonstrations by lecturers or their assistant. Whereas the real classroom scientific inquiry, data are primarily collected from primer resources. In other words, the scientific inquiry in lecture changes data collection skills from primary resources in the real classroom scientific inquiry (laboratory activities) to secondary resources.

The scientific inquiry-based instruction in lecture involves investigations that begin with what the student already knows (both prior knowledge and facilitated knowledge); followed by formulating question(s); then data collection (planning and doing investigation) and analysis; and finally constructing and discussing explanation based on data, conclusion(s) and evidence(s), and connecting the finding with scientific explanations. In instructional processes, university students are engaged in learning content as well as how to organize and reason about the content, doing activities as well as control, reflect upon and evaluate their learning, and scaffold for working together to discuss evidence and connect their findings with scientific explanations. By these processes, university students retrieve and apply their ideas to capture phenomena, pattern, and deviation of the pattern; formulate question(s); plan and conduct investigation; analyze data; understand deep meaning of phenomena, pattern, deviation of the pattern, and conclusion; develop and construct explanations based on evidence, and connect their findings with scientific explanations. These mind activities improve students' reasoning and argumentation that finally promote their competencies to solve problems.

The measurement of scientific knowledge in this study emphasized the students’ deep understanding that facilitates the retrieval and application of ideas as well as the development and construction of evidence-based explanations. Subsequently, students in the scientific inquiry-based instruction in lecture group performed better in assessment. This result is in line with previous reasons for an experimental group where students activated their mind for learning so that their learning outcome was better. On the other hand, traditional science instruction is largely focused on a knowledge transmission from lecturer or learning materials to the learner. The process emphasized more on scientific knowledge and less on scientific competencies, including reasoning and argumentation. So, it’s reasonable if control group students did not perform as well as experimental group students in scientific knowledge test in which the problems were constructed based on the deep understanding, reasoning, and argumentation.

Outcomes in this research may contribute to improving quality of education, especially for chemistry instruction in education institution with limited laboratory facilities. Indonesian education, like other developing countries, has limited facilities, including chemistry laboratory. This situation demands instructor to design non-laboratory instruction that pays attention to the character of science and students’ learning outcome when learning science, i.e. scientific knowledge, scientific inquiry competencies (scientific inquiry knowledge and skills), and nature of science (Hodson, 1992; Levy et al. 2011). With slightly different meaning, NGSS (Next Generation Science Standard) uses term core ideas for scientific knowledge, practices for scientific inquiry competencies, and crosscutting concepts for nature of science (NRC, 2012).

The research outcomes also can be used to reduce negative impact of basic chemistry contents separation, i.e. to be theoretical basic chemistry and laboratory work of basic chemistry courses. This separation pays less attention to aspects of scientific inquiry knowledge and skills and nature of science. Therefore, scientific inquiry-based instruction in lecture strategy can be used to overcome the limitation in schools’ laboratory facilities and separation of basic chemistry contents into basic chemistry and laboratory work of basic chemistry in instruction of university chemistry.

The Difficult Sub-topic of Acid-base Chemistry for University Student

The most difficult sub-topic of Acid-base Chemistry for university students in this study was salt hydrolysis concept. This result was consistent with Demircioglu (2009) which shown that students hold many misconceptions in salt hydrolysis concept, i.e. all salts are neutral and salts don't have a value of pH.

In this instrument salt hydrolysis was assessed by problems number 14 and 25 as provided in the following boxes:

14. Which of the following salts undergoes hydrolysis?
A. $NaNO_3(aq)$ B. $Ca(NO_3)_2(aq)$ C. $Mg(NO_3)_2(aq)$
D. $Ba(NO_3)_2(aq)$ E. $Sr(NO_3)_2(aq)$

Among 54 participants, only five students gave the right answer. Four of them were from the experimental group, and one was from the control group. For solving this problem, students have to connect this concept to three other understandings, they are salts coming from weak acids or bases only that undergoes hydrolysis, all bases of alkali metals are a strong base, and the alkalinity of bases of alkaline earth metals increases from top to bottom of the periodic table. The right answer is C as $Mg(NO_3)_2$ comes from strong acid HNO_3 and weak base $Mg(OH)_2$. So, only Mg^{2+} of the salt that undergoes hydrolysis as follow:

$$Mg^{2+}(aq) + H_2O(l) === Mg(OH)_2(aq) + 2OH^-(aq)$$

25. Check the truth and the logic of each of the following statements and then choose:
A. IF statement I is true; statement IIis true; statement III is the logic consequence of statement I and statement II.
B. IF statement I is true; statement II is true; statement III is not the logic consequence of statement I and statement II.
C. IF statement I is true; statement II is fault; statement III is not the logic consequence of statement I and statement II.
D. IF statement I is fault; statement II is true; statement III is not the logic consequence of statement I and statement II.
E. IF statement I and II are fault; statement III is not the logic consequence of statement I and statement II.

The statements:
(I) In equivalent point, the concentrations of acid and base are the same.
(II) In end point of titration, the color of indicator changes from acid condition to base and conversely.
(III) In titration, end point and equivalent point are the same.

For this problem, from 54 participants only five students gave the right answer. As in problem number 14, there were four students from the experimental group and one from the control group who chose the right answer. To solve this problem, students have to understand the concepts of equivalent point, the concentration of OH^- ion, H^+ ion, acid substance, and base substance, the end point of the acid-base titration, and the change of indicator color. It is difficult for most students to understand the difference between the concentration of OH^- ion and base substance or concentration of H^+ ion and acid substance, equivalent point and end point of the titration, and neutral solution and change the color of the indicator. As pointed out by Demircioglu (2009), students held the misconception that the indicator helped occurring neutralization reaction, and the indicator changed color at pH of 7. So the right answer of this problem is D.

CONCLUSIONS AND IMPLICATIONS

This study has developed and investigated the effectiveness of a new instructional strategy which we named it scientific inquiry-based instruction in lecture. The instructional strategy was proven to be effective to increase students' understanding on scientific knowledge of Acid-base Chemistry. The result implies that the scientific inquiry in lecture instructional strategy developed in this study can be applied in university as chemistry instruction for reducing the negative impact of Basic Chemistry Content separation (into Theoretical Basic Chemistry Course and Laboratory Work of Basic Chemistry Course) and in school for overcoming the limitation of laboratory facilities.

This study also shows that salt hydrolysis is the most difficult topic of Acid-base Chemistry concepts. The result is in line with of Demircioglu's finding (2009). As we know, to understand this topic, student need to understand other fundamental chemistry concepts, such as weak and strong electrolytes, chemical equilibrium, mole, nature of solutions, particulate nature of matter, chemical reactions and chemical change (Demircioglu, 2009). This result also supports the important of students' prior knowledge or prerequisite concepts confirmation before moving to learn to more complex concepts.

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