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Full Length Research Paper

The effects of guided inquiry instruction incorporating a cooperative learning approach on university students' achievement of acid and bases concepts and attitude toward guided inquiry instruction

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The purpose of this study was to investigate the effects of guided inquiry instruction incorporating with cooperative learning environment on University students' achievement of acid and bases concepts and attitude toward guided inquiry instruction. The subject of this study consisted of 55 first year University students from two intact classes of a Chemistry Course instructed by the same teacher. One of the classes was randomly assigned as the experimental group and the other was assigned as the control group. Researcher prepared worksheets which were related to acid- based concepts based on guided inquiry instruction from the book which is written by (Moog and Farrell, 2006). The experimental group was cooperatively studied worksheets in the groups while the control group was individually studied worksheets in the class. Acid and Bases Achievement Test (ABAT) was administered to the experimental and the control groups as pre and post-tests to measure the students' understanding of acid and bases concepts and Attitude Toward Guided Inquiry Instruction Scale (ATGIIS) was also used as pre and post-test for both of groups. Multi Variance Analysis (MANOVA) was used to analyze the data. The results showed that students in the experimental group had better understanding of acid and bases concepts and more positive attitude toward guided inquiry instruction.

Key words: Guided inquiry, cooperative learning, acid and bases.

INTRODUCTION

Provision of an effective learning and teaching by scientific research method is main goal of many educational organizations (AAAS, 1993; National Research Council [NRC], 2001). Scientific inquiry is defined by National Science Education Standards (NSES) and (NRC, 1996) as many different ways that scientist investigate the natural world and put forward explanations based on the findings they provide from their researches. Inquiry is a method of forming questions about natural world, finding answers, studying and understanding it thoroughly as scientists do rather than knowing generally through an expert or by other means. It is a widely accepted fact by educators that inquiry is very important to reach new knowledge.

Teaching and learning processes during which learners ask their own questions, plan their own inquiries, analyze and discuss their findings and construct their own understandings proves learning to be more effective and long-lasting. Inquiry model requires a high degree of communication among environment, content, materials and learners and teachers (Orlich et al., 1998). The most important feature of this method is to enable both teachers and learners to be researchers, idea propagators and problem solvers. Furthermore, it has some positive consequences such as making students active, developing their understandings, improving their research skills and understandings of the nature of the science (Metz, 2004; Wallace et al., 2004).

Many educators discuss the nature of the inquiry by making use of mostly two concepts such as open inquiry and guided inquiry (Hassard, 2005). Open inquiry is described as a student-centred approach. Students, in this approach, form their own problems and hypotheses, make plans for a scientific research, carry out these researches in order to test their hypothesis and discuss their findings with other friends (Colburn, 2000). Studies on research method conclude that this approach has a positive influence on students' academic success (Blonder et al., 2008; Ertepinar and Geban, 1996), their development of scientific process skills (Basaga te al., 1994) and their attitudes towards science lessons (Shepardson and Pizzini, 1993). However, it was reported that this approach did not have a significant effect on improving students' academic achievements and developing their scientific process skills (Berg et al., 2003; Khishfe and Abd-El-Khalick, 2002; Klahr and Nigam, 2004; Schneider et al., 2001). Different interpret-tations attributed to this concept by researchers restrict reform works about scientific inquiry to be understood by the teachers (Wallace and Kang, 2004).

In this approach, scientists' real works are mostly revealed. Open inquiry requires a higher order thinking (Orlich et al., 1998). In standards and benchmarks, making a research does not need to follow science management stages step by step (NRC, 1996; AAAS, 1993). Though research facilitates the construction of a problem solving logic stemming from a scientific method, it does not necessarily define each step of the scientific method. Standards (NRC, 1996) can not be interpreted as advocating a scientific method. Conceptual and methodological skills advocate a logical sequence but they do not advocate a strict approach for a scientific research. Open inquiry is intellectually challenging for learners and difficult to implement for teachers (Rop, 2002).

Although science teachers play an important role in the implementation of this inquiry model, teachers' this approach faces many difficulties during implementation. Cheung (2007) listed the obstacles emerged during the implementation of this inquiry method in a study with chemistry teachers as follows: insufficient time, teachers' beliefs, scarcity of effective research materials, pedagogical problems, management problems, crowded classes, security issues, fear of encouraging students to misunderstandings, students' complaints, fear of assessment, scarcity of teaching materials etc. The reason for this is the lack of methodological knowledge as well as scientific content (Shedletzky and Zion, 2005). Teachers, beside academic support, need to be informed about learning and teaching processes through research (Lim, 2004) and the usage of guided inquiry methods (Cheung, 2007) in order to resolve teachers' lack of knowledge according to social constructivist approach of learning.

According to Furtak (2006), scientific teaching stands somewhere between the boundaries of the traditional method, in which certain answers known by the teachers are transferred to the students and the open inquiry method, in which students construct their own problems and problem solutions. This version is called guided inquiry method. Guided inquiry is to integrate the scientific and constructivist rationales together with the facts, principles and rules accepted as scientific and stressed by contemporary science education reforms (Magnusson and Palinscar, 1995). Guided inquiry could be defined as interacting with concrete materials to gain knowledge about some chemistry concepts by making use of the guidance made to a certain degree apart from the teacher in order to be able to solve a problem (Lewicki, 1993).

In guided inquiry method, teachers and learners play a crucial role in asking questions, developing answers and structuring of materials and cases. The usage of guided inquiry method is very important in transition from lecturing method to other teaching methods which are less and more clearly structured for alternative solutions. Guided inquiry activities help students to develop their individual responsibility, cognitive methods, report making, problem solving and understanding skills. According to National Research Council (NRC, 2000), guided inquiry environments can best facilitate focusing on learning the development of certain scientific concepts, but while students in the teachers' guidance focus their attention on to the content , they have less suitable means for discovering scientific thinking processes and gaining experience (Kai and Krajcik, 2006).

Students are expected to investigate the chemical concepts, development shapes, written explanations and data by the guided inquiry method used in this study. Each concept includes chemical activities that consist of different parts. These are one or many models or knowledge modules, critical thinking questions, examples and problems. Students are expected to discover important chemical concepts and principles with individually and cooperatively based on the teaching materials which is prepared with guided inquiry instruction. The main purpose of this study was to investigate the effects of guided inquiry instruction incorporating with cooperative learning environment to university students' achievement of acid and bases concepts and attitude toward guided inquiry instruction. The study was done by the following research questions:

1. Is there a significant mean difference between effects of guided inquiry instruction in a cooperative learning environment and individual learning environment on university students' achievement of acid and bases concepts?
2. Is there a significant mean difference between effects of guided inquiry instruction in a cooperative learning environment and individual learning environment on University students' attitude toward guided inquiry instruction?

METHOD

Subjects

The subjects of this study were 55 first year undergraduates from two different classes enrolled to General Chemistry course in the Department of Primary Science Education. One class was randomly assigned to the experimental group (n = 28) while the other group formed the control group (n = 27). Students in the experimental group were instructed with Guided Inquiry n cooperative learning environment, while students in control group received Guided Inquiry individually. General Chemistry is a 4 h lecture per-week and a compulsory course for all undergraduate students in the first year. Acid and Bases Unit is covered during the spring semester. Topics related to acid and bases covered were definitions of acid and bases based on the different acid and bases theory, strong and week acids and bases, acid and bases dissociation, PH calculations for strong and week acids and bases, relative acid strength, and acid/base strength of conjugate pairs. All students were taught by the same instructor and both of the groups received 12 h instruction.

Instruments

In order to address the research questions, an acid and bases achievement test and attitude toward guided inquiry instruction scale were administered to the subjects before and after teaching. The test used in the study described below.

Acid and Bases Achievement Test (ABAT): This test included 30 multiple choice items. Some of the test items were taken from Bodner (2001) and Bradley and Mosimege (1998). The tests were evaluated by two instructors to appropriateness of items for content validity. The Cronbach's alpha reliability of the tests was found as 0.83. Some examples from tests are given in Appendix A.

Attitude toward guided inquiry instruction scale (ATGIIS): ATGIIS was developed by researcher after related literature was investigated. This scale measures the students' attitudes toward guided inquiry instruction and contains 19 likert-type items (strongly agree, agree, undecided, disagree and strongly disagree). This scale was applied 55 students after they experienced with solubility unit based on the guided inquiry instruction and the reliability of this scale was found to be 0.86. Some of the items from ATGIIS were given in Appendix B.

Treatment

This study was conducted over a 12 lecture hours. The experimental and control groups were given ABAT and ATGIIS as pretests at the beginning of the study. Both of the groups gained experience with guided inquiry instruction in solubility concepts before the acid and bases unit. Teaching materials which prepared based on guided inquiry instruction, from the book which is written by Moog and Farrell (2006), in acid and bases unit given to the both experimental and control groups, the difference between the groups is explained below. Some of examples of teaching material were given in Appendix C.

In the control group, students studied teaching materials in class individually and wrote their response proper places in the worksheets. After the answers were given, the lecturer asked randomly selected student to share his or her findings with the class. This process was repeated for every critical thinking question, exercises and problems prior to the beginning of the treatment in the experimental group, the students were assigned to four member-learning teams in a small group-learning environment. The groups were heterogeneous with respect to their achievement: one high, two average and one low achiever students for their previous science exam scores. Students in the experimental group were trained about cooperative learning approach and a detailed description of the cooperative learning approach were distributed to all of the students before the treatment.

Students in experimental group studied all of the teaching materials in class cooperatively. This time, students were asked to answer every critical thinking questions, exercises and problems first in pairs and then in groups of 4. When groups completed their work for each question and reached a consensus, the teacher asked some of the groups to explain their answers. The teacher continued asking questions until one of the groups provided the expected answer. A speaker is assigned for each group to report their explanations and the speakers within a group are changed for each answer. The teacher got answers selectively from each student in the control group and the groups of 4 in the experimental group. However, in order to keep the learning environment fair, the teacher gave equal chances to the students to report their explanations.

For this purpose, the teacher used a check list. If the answers were correct, positive feedback was given, if not, clues were provided or the activity was redone in order to reach the right answer. If the correct answer was still not found, the teacher explained the right answer with reasons. Only after the successful completion of these steps, another activity was used. Students' grade levels, teaching material related to acid and bases concepts based on the guided inquiry instruction and the instructional time were held constant.

At the end of the treatment, both the experimental and the control groups were administered ABAT and ATGIIS as post-tests.

Analysis of data

Dependent variables of the study were the students' achievement scores of ABAT and ATGIIS. Independent variables of the study were the different types of instructions employed. The data obtained from pre- and post-tests were analyzed by using SPSS (Statistical Package for Social Sciences) (Norusis, 1991).

RESULTS

Students' mean, standard deviation and independent sample t-test results for pre- ABAT in experimental and control groups were given in Table 1. It is seen from the Tables 1 that students' mean scores of pre- ABAT were similar for the experimental and the control groups and also there was no significant mean difference between control and experimental groups with respect to the pre- ABAT scores ($t(53) = 0.234$; $p > 0.05$). Pearson correlation was used the test whether pre- ABAT scores were statistically significant correlation post - ABAT scores. The result showed that there was no significant correlation between pre and post- ABAT scores ($r = 0.108$, $n = 55$, $p > 0.05$).

Students' mean, standard deviation and independent sample t-test results for pre- ATGIIS in experimental and control groups were given in Table 2. It is seen from the Tables 2 that students' mean scores of pre- ATGIIS were similar for the experimental and the control groups and also there was no significant mean difference between control and experimental groups with respect to the pre- ATGIIS scores ($t(53) = 0.123$; $p > 0.05$). Pearson correlation was used the test whether pre- ATGIIS scores were statistically significant correlation post - ATGIIS scores. The result showed that there was no significant correlation between Pre and post- ATGIIS scores ($r = 0.083$, $n = 55$, $p > 0.05$).

In order to investigate the effects of guided inquiry instruction incorporating a cooperative learning approach

Table 1. Comparison of experimental and control groups pre-ABAT scores.

Group	N	X	sd	t	df	P
Experimental G.	28	8.11	2.67	0.234	53	0.816
Control G	27	7.93	1.81			

N = 55; p > 0.05

Table 2. Comparison of experimental and control groups pre-ATGIIS scores.

Group	N	X	sd	t	df	P
Experimental G.	28	62.57	7.70	0.123	53	0.902
Control G	27	62.33	6.55			

N=55; p > 0.05

on students' post-ABKT and ATGIIS scores, MANOVA was run for independent variable.

One of the assumptions of MANOVA is the homogeneity of covariance matrices. In order to test this assumption, Box's Test was used. This analysis revealed that observed covariance matrices of dependent variables are equal across the experimental and the control groups (F = 2.84, p < 0.05). Therefore, this assumption was violated. Levine's Test was used to check the assumption that error variance of dependent variables is equal across the experimental and control groups. All significant values for dependent variables, post- ABAT scores (F (1. 53) = 3.264; p > 0.05) and post- ATGIIS scores (F (1.53) = 0.955; p > 0.05), were greater than 0.05, meaning the equality of variances assumption was not violated.

After checking whether assumptions were violated, Pillai's Trarace was used to test the effects of guided inquiry instruction incorporating a cooperative learning approach and guided inquiry instruction on students' achievement of acid and bases concepts and attitude toward guided inquiry instruction. Because there is violation of the homogeneity of covariance matrices assumeption and group sizes are similar.

The results showed that there were significant differrences between the dependent variables in the teaching methods used (Pillai's Trarace = 0.218, F (2.52) = 7.232, p < 0.05). Following up, ANOVA was needed to decide which dependent variables were responsible for the significant effects on students' performance. Students' mean and standard deviation for post- ABAT and post-ATGIIS in experimental and control groups were given in Table 3.

Tables 4 and 5 contain the summary of ANOVA comparing the mean scores of students' performances in both the experimental and the control groups with respect to the post- ABAT and post- ATGIIS scores, respectively.

The results indicated significant treatment effects (F (1.53) = 6.213, p < 0.05). The students in the experimental group who were instructed with guided inquiry instruction incorporating a cooperative learning approach demonstrated better performances on post- ABAT scores than the control group students who were instructed with guided inquiry instruction individually.

The results indicated significant treatment effects (F (1.53) = 10.281, p < 0.01). The students in the experimental group who were instructed with guided inquiry instruction incorporating a cooperative learning approach demonstrated better performances on post- ATGIIS scores than the control group students who were instructed with guided inquiry instruction individually.

Table 3. Students' mean and standard deviation for post- ABAT and post- ATGIIS.

Group	Post- ABAT			Post- ATGIIS	
	N	X	sd	X	ss
Experimental G.	28	23.29	3.88	69.54	8.10
Control G	27	21.07	2.53	61.70	9.95

N = 55

Table 4. Summary of ANOVA comparing the mean post- ABAT scores of the students in the experimental and the control groups.

Sources	df	Mean square	F	p
Experimental G.	1	67.234	6.213	0.016*
Control G	53	10.822		
Significant at p < 0.05				

Table 5. Summary of ANOVA comparing the mean post- ATGIIS scores of the students in the experimental and the control groups.

Sources	df	Mean square	F	p
Experimental G.	1	843.152	10.281	0.002*
Control G	53	82.011		

Significant at p<0.01

DISCUSSION AND CONCLUSION

The main purpose of this study was to compare the effects of guided inquiry instruction incorporating a cooperative learning approach and individual approach on University students' achievement of acid and bases concepts and attitude toward guided instruction. The main differences between the two instructional approaches were as follows: students in the experimental group discussed all models, critical questions, exercises and problems cooperatively in small groups, while students in the control group read and did all models, critical questions, exercises and problems individually in class According to the findings of the collected data for research question 1 for this study, it's been determined that when guided inquiry are used along with a cooperative learning approach compared to individual approach, University students' achievement of the acid and bases concepts have increased more. Teaching materials were prepared for this study improved the students learning environment and helped students to be more active. Bailey (2008) reported that a course designed based on the student centered learning help us to understand how students learn with material being developed. This result supports the findings that when the teaching materials are used with cooperative learning environment, students' performance in science concepts develop better (Bailey, 2008; Eskilsson, 2008; Bilgin, 2006; Hofstein and Lunetta, 2004; Walters and Soyibo, 2001; Westbrook and Rogers, 1994).

In individual learning environment, students study alone, but in the cooperative learning approach students study with others and share their ideas with each other. This approach allows students to work in groups and enables them to develop social interactions. Activities used in cooperative learning help students more active and speak clearly (Bailey, 2008). The tasks requiring social interactions will stimulate learning and will enable students to recognize that an action should be taken with reference to others.

According to the findings of the collected data for research question 2 for this study, it's been determined that when guided inquiry are used along with a cooperative learning approach compared to individual approach, University students' attitude toward guided inquiry instruction has developed in a positive manner. According to the findings of many studies conducted by Chang and Tsai (2005), Taraban et al. (2007), Zacharia (2003), Siegel and Ranney (2003), Schibeci and Riley (1986), Simpson and Oliver (1990), Oliver and Simpson (1988), the nature of science teaching affects the student attitude strongly.

The greater success and positive attitude toward guided instruction of students in experimental group can be explained as follows: students' participation of teaching materials which is prepared based on the guided inquiry instruction in small groups helped them to acquire meaningful learning by making relationships among concepts and discussion of concepts helped students to recognize their ideas, share their ideas and facilitate their understanding as well as encourage their conceptual restructuring and attitude toward guided instruction.

As a result, when teaching materials which are prepared based on the guided inquiry instruction used in cooperative learning environment, students have developed their performance of acid and bases concepts and positive attitude toward guided instruction better than students are studies with alone.

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Appendix

Appendix A: Some example of acid and bases achievement test

1) Which one of the following does show both properties of acid and bases?
(A) NaOH (B) NH_3 (C) HCN (D) HSO_4^{-1} (E) H_2

2) Same of strong and week acid and bases dissociate in the water very well. For example, KOH and NH_3 are compounds which are so much dissociate in the water. Based on this information which one of the following is correct ?
(A) KOH is strong elctrolyte (B) NH_3 is strong elctrolyte (C) KOH and NH_3 are strong elctrolyte (D) KOH and NH_3 are week elctrolyte (E) non of them

3) What is the pH for 3,2 X10^{-5} M solution of $Mg(OH)_2$?
(A) 10 (B) 9,8 (C) 4,2 (D) 7,8 (E) 11,2

4) What are the hydroxide ion concentration of a solution at 25 ^{0}C that is 0,02 M methylamine (CH_3-NH_2) ? (for methylamine , Kb = 4,86x10^{-4})
(A) 3,9 x10^{-3} (B) 4,5 x10^{-3} (C) 3,12 x10^{-3} (D) 4,9 x10^{-3} (E) 5,3 x10^{-3}

5) What is the pH of a buffer solution that is 0,05 M CH_3COOH and 0,1 M CH_3COONa ? (for CH_3COOH, Ka = 1,8x10^{-5})
(A) 6 (B) 6,3 (C) 5,5 (D) 5,05 (E) 6,05

Appendix B. Some example of attitude toward guided inquiry instruction scale

		Strongly agree	Agree	undecided	Disagree	Strongly Disagree
1	I think that chemistry subjects offered with guided inquiry instruction in the class increase my thinking skills.					
2	I think that chemistry subjects offered with guided inquiry instruction in the class, helped to show my thinking skills.					
3	I think that chemistry subjects offered with guided inquiry instruction in the class increases my interest toward chemistry.					
4	I think that chemistry subjects offered with guided inquiry instruction in the class increases my achievement of chemistry course.					
5	I think that chemistry activities used with guided inquiry instruction help me to inferences about chemistry subjects.					
6	I think that chemistry activities used with guided inquiry instruction help me to find different solution for chemistry problems.					

Appendix C: Students' worksheets related to guided inquiry acids and bases

Model 1: Two definitions of acids and bases

Arrhenius definitions: An acid is a substance that produces hydronium ions, $H_3O^{+1}{}_{(aq)}$, When it is added to water.
A base is a substance that produces hydroxide ions, $OH^{-1}{}_{(aq)}$, when it is added to water.

Bronsted-Lowry definitions: An acid is a substance that donotes a proton, H^{+1}, to another species.
A base is a substance that accepts a proton, H^{+1}, from another species.
Acid-base reaction is one of the most important types of chemical reactions.

Table 1. Equilibrium constants for some acid-base reactions.

Reaction	K	
$HCl_{(g)} + H_2O_{(s)} \rightleftarrows H_3O^{+1}{}_{(aq)} + Cl^{-1}{}_{(aq)}$	$2x10^4$	(1)
$NH_{3(g)} + H_2O_{(s)} \rightleftarrows NH_4^{+1}{}_{(aq)} + OH^{-1}{}_{(aq)}$	$3,3x10^{-7}$	(2)
$HCN_{(aq)} + H_2O_{(s)} \rightleftarrows H_3O^{+1}{}_{(aq)} + CN^{-1}{}_{(aq)}$	$1,1x10^{-11}$	(3)

Critical thinking questions

1a) What chemical species are the Arrhenius acids in the forward reactions (1) - (3)?
b) What chemical species are the Arrhenius bases in the forward reactions (1) - (3)?
c) What chemical species are the Bronsted-Lowry acids in the forward reactions (1) - (3)?
d) What chemical species are the Bronsted-Lowry bases in the forward reactions (1) - (3)?
2) Is it possible for a substance to act as both an acid and a base? Explain your reasoning.
3) Based on the data in Table 1, which do you think is considered the stronger acid, HCl or HCN? Explain your reasoning.
4) Consider reaction (1).
a) What species results from the loss of a proton from Bronsted –Lowry acid in the forward reaction ?
b) Does the species indicated in part a) (the answer that you gave) act as an acid or a base when the reverse of reaction (1) occurs ?
c). What species results from the gain of a proton by Bronsted–Lowry base in the forward reaction ?
d). Does the species indicated in part c) act as an acid or a base when the reverse of reaction (1) occurs ?
e). Answer parts a)-d) for reactions (2) and (3) also. Describe any general relationship that you observe using a grammatically correct English sentence.

Model 2: Conjugate pairs

Within the Bronsted- Lowry model, certain pairs of molecules are described as a conjugate acid-base pair. The two species in a conjugate acid-base pair differ by a proton only. A base is said to have a conjugate acid, and an acid is said to have a conjugate base.

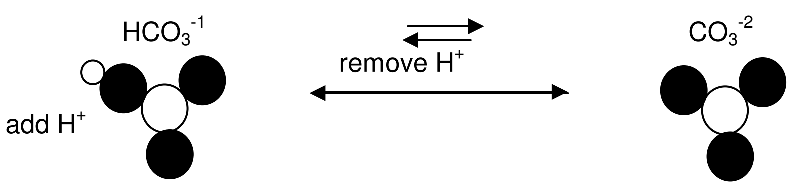

Table 2. Example of conjugate acid-base pairs.

Acid	Base
H_2CO_3	HCO_3^{-1}
HCO_3^{-1}	CO_3^{-2}
H_3O^{+1}	H_2O
H_2S	HS^{-1}

A Conjugate acid-base pair differs by a proton, H^+. The species with more protons is the acid.

Critical thinking questions

5). Why is the charge on the hydrogen sulfide ion in The Table 2 given as -1?
6). Answer and explain each of the following:

a). What is the conjugate acid of NH_3 ?
b). What is the conjugate acid of H_2O ?.
c). Define a conjugate acid-base pair?

Exercises

1). Give the conjugate base of each of the following: HSO_4^{-1} ; HCO_3^{-1}; H_2O ; OH^{-1} ; H_3O^{+1} ; NH_4^{+1}; $CH_3NH_3^{+1}$; HF ; CH_3COOH.
2). Give the conjugate acid of each of the following SO_4^{-2} ; CO_3^{-2} ; H_2O ; OH^{-1} ; O^{-2} ; NH_3 ; CH_3NH_2; CN^{-1}; CH_3COO^{-1}; F^{-1} ; HCO_3^{-1} ; NH_2^{-1}
3). For each of the folllowing reactions:

$$H_2SO_{4(aq)} + H_2O_{(s)} \rightleftharpoons H_3O^{+1}_{(aq)} + HSO_4^{-1}{}_{(aq)}$$

$$HSO_4^{-1}{}_{(aq)} + H_2O_{(s)} \rightleftharpoons SO_4^{-2}{}_{(aq)} + H_3O^{+1}_{(aq)}$$

$$H_2O_{(s)} + H_2O_{(s)} \rightleftharpoons H_3O^{+1}_{(aq)} + OH^{-1}_{(aq)}$$

$$HCN_{(aq)} + CO_3^{-2}{}_{(aq)} \leftrightharpoons HCO_3^{-1}{}_{(aq)} + CN^{-1}_{(aq)}$$

$$H_2S_{(g)} + NH_{3(s)} \rightleftharpoons HS^{-1}_{(am)} + NH_4^{+1}{}_{(am)}$$

(am) = dissolved in liquid ammonia

a) Which reactant is the acid?
b) Which reactant is the base?
c) Find the two conjugate pairs present in the reaction?
5). Complete the following table of conjugate acids and bases:

Acid	Base
H_2S	
	S^{-2}
	NO_2^{-1}
H_3PO_4	
	OCN^{-1}
H_3O^{+1}	
OH^{-1}	
	F^{-1}
	HPO_4^{-2}
HOCl	
HSO_4^{-1}	