IMPACT OF THE CURRICULUM REFORM ON PROBLEM SOLVING ABILITY IN CHEMISTRY: AN EX POST FACTO STUDY ON CHEMISTRY EDUCATION STUDENTS

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ABSTRACT

An ex post facto study was conducted to examine the effect of the curriculum reform on 60 Dilla University chemistry education students' problem solving ability. The study shows that the curriculum reform that shifted university introductory courses of the old curriculum into preparatory school levels in the new curriculum significantly hampered students' problem solving ability. *[AJCE, 2(3), July 2012]*

INTRODUCTION

In dealing with the issue of problem solving orientation in chemistry education, we may need to first consider the larger question why we teach chemistry? There is a relationship between chemistry and everyday life. However, students' at all educational levels make little connection between chemistry that happens in the classroom and that happens outside of classrooms. Students perceive each chemistry topic or intellectual knowledge as a separate entity, which is detached from the physical world. However, intellectual knowledge is not separate from the physical world; rather it is symbolic and abstract representation of the physical world (1).

According to Krulik and Rudnick (2) the gap between chemistry classrooms and the outside world can be narrowed down by giving an emphasis on development of problem solving in chemistry and setting up a positive mood in the classroom. Likewise Soden (3, p.133) claims that "learning is problem solving". Therefore, teaching problem solving is teaching people how to learn, so is problem solving in chemistry education.

Kalbag (4) states that problem solving orientation in chemistry education has an importance in that problem solving converts information into knowledge. Kalbag further states that problem solving always produces a knowledge that is much more active and usable than information acquired in other ways (4). This can help not only to solve professional or life problems, but also to learn and convert information stored in memories into usable knowledge structures. And hence, problem solving orientation in chemistry education needs a critical concern at least at the higher education levels.

In 1994 the Federal Democratic Republic Government of Ethiopia has introduced a new Education and Training Policy which states that the objective of higher education is to produce problem solving professionals in their field of studies (5). More importantly, development of problem solving skills of teachers through a learner-centered approach and curriculum that integrates content and methodology has been the objective of teacher education (6). Following the new education and training policy the higher education curriculum has been reformed.

As a result of the curriculum reform the first year university introductory (general) courses of the old curriculum has been moved into preparatory schools. Consequently in the new curriculum, the first year university introductory courses of the old curriculum are taught to students within their two years stay in the preparatory schools (grades 11 and 12). Hence, the two year study in the preparatory schools is presumed to be equivalent with a one year study or the first year university courses of the old curriculum.

Upon completion of the first year introductory courses at preparatory schools (grade 12), students who scored the minimum pass mark (as decided by the Ministry of Education) are directly admitted to universities in different departments. Hence the study has been designed to investigate the impact of the new curriculum on students' chemical problem solving ability compare with the impact of old curriculum. The study was conducted while the old and the new curriculum were run in parallel.

THEORETICAL FRAMEWORK

Variables which determine problem solving ability

Frazer and Casey in Kornhouser (7) define problem solving in chemistry: as the result of application of knowledge and procedures to problem situations. And they propose four stages, such as definition of the problem, selection of appropriate information, combining the separate pieces of information and evaluation of the solution. Kornhouser (7) remarks that the best chance for success in chemical problem-solving rests on the combination of strong background knowledge of chemistry, good knowledge of problem solving strategies and tactics, and confidences. Similarly, many academics note that in any educational context and in life in general problem solving process is the interaction of factual knowledge, cognitive and meta-cognitive strategies, experiences, belief systems and social factors (8). Therefore, problem solvers need to posses well coordinated cognitive components of the three critical cognitive components of problem solving process: knowledge structure, cognitive functioning and belief system towards the task (9).

Chemical knowledge structure

Knowledge is one of our cognitive constructs that are necessary to consciously identify and solve problems. For instance chemistry problem solvers need to have chemistry knowledge. Many psychologists and researchers, working in problem solving, argue that problems never been solved in vacuum. Hence the problem solver should possess a background knowledge related to the problem at hand.

Academics such as Taconis, Ferguson-Hessler and Brockkp (10); Soden (11); Borich, McCormick, Tombari, and Pressley ([12]; and Bunce and Gabel (13) note that knowledge structure is a basic and a core components of problem solving that problem solver should posses to tackle problems in any professional area of life in general. Borich, McCormick, Tombari, and Pressley (12) assume that knowledge is a determinant of performance. They added that those who posses domain specific knowledge processes information efficiently than domain novices. Similarly Simon and Hayes in Bunce and Gable (13) remark that if one wants to solve a problem, there is no substitute for having prerequisite knowledge.

Studies conducted on college chemistry students show that using conceptual understanding is necessary for problem solving, and show that problem solvers based on conceptual understanding performs twice than algorithmic (traditional) problem solvers (13). For instance, Gabel and Bunce from their study on chemistry students' remark that in order to solve a chemistry problem in an acceptable manner, the problem solver must have both scientific and procedural knowledge. In this connection Taconis, Ferguson-Hessler and Brockkp presented a model (see figure 1 below.) that shows the basic role of scientific and procedural (skill) knowledge on learning cognitive tasks or problem solving in science (10). In sum, what studies on problem solving show is that, well grounded knowledge structure is a basic component of successful problem solving.

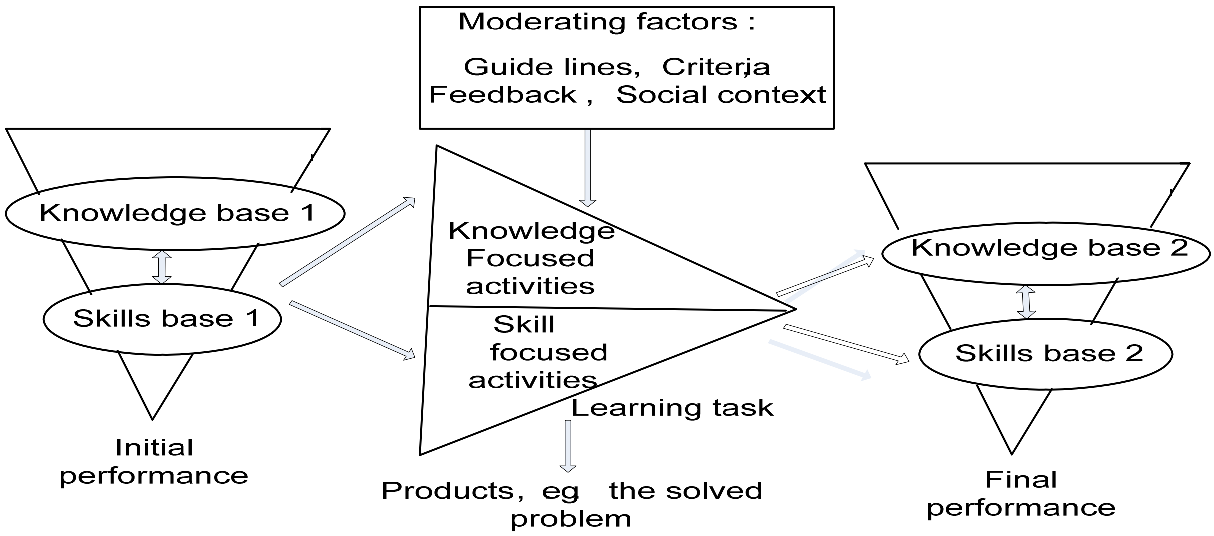

Figure 1. Basic view on learning to perform a cognitive task (10)

In light of this model (fig. 1), the moderating factors (or independent variables) and final performance (or dependent variables) of this study were:

1. Students origin and year level (i.e. independent variables), and
2. Students' problem solving ability (i.e. dependent variables).

Here students' origin refers to preparatory and freshman origin. Preparatory origin students' are those who attended university introductory courses in preparatory schools, but those who attended their introductory courses in Dilla University are freshman origin students.

Thus this study has been designed to determine the impact of origin and year level on problem solving ability of chemistry education students.

Knowledge structure of successful vs. unsuccessful problem solvers

Knowledge structure of successful problem solvers should be organized in terms of concepts, principles, rules, conditions and procedures Gable and Bunce (13) and Sugrue (9). Gable and Bunce , and Sugrue state that, if the knowledge structure of good problem solvers is well integrated, the triggering of one of the nodes (concepts) of the structure will activate the whole knowledge structure and hence process of accommodation will come into action. However, the knowledge structure of poor problem solvers is deemed to be fragmented and unconnected (9).

Assessment of knowledge structure

While we are talking about knowledge structure, it is about a way how domain specific knowledge structure is composed from facts, concepts and principles interlinked (chunked) into a usable forms of knowledge organization, eg knowledge structure about thermodynamics. Therefore assessment of knowledge structure involves the assessment of concepts, principles, and their interrelations, how concepts are linked to conditions and procedures (9).

RESEARCH OBJECTIVES AND QUESTIONS

The study has the following objectives:

1. Comparing problem solving ability of Chemistry Education students with reference to year level.
2. Comparing problem solving ability of chemistry education students with reference to their origin, i.e.
   a) Students who took their introductory courses in university (freshman origin students) with
   b) Students who took their introductory courses in preparatory schools (preparatory origin students).

The main research questions are:

1. Does the curriculum reform that moved an introductory university courses from university to preparatory schools have an impact on chemistry education students' problem solving performance in chemistry?
2. Does student's year level have an impact on chemistry education students' problem solving performance in chemistry?
3. Does the curriculum reform that moved an introductory university courses from university to preparatory schools have an impact on chemistry education students' problem specific and easily accessible knowledge structure?
4. Does student's year level have an impact on chemistry education students' problem specific and easily accessible knowledge structure?

RESEARCH METHODOLOGY

The study applied the proactive ex post facto research design. This design is selected for students' origin and year level are variables which cannot be manipulated. As a result the three groups of subjects were selected based on the preexisting independent variables: 1) origin: freshman origin and preparatory origin students, and 2) year level: third and fourth year students.

The population of the study was composed of groups of 46 third year freshman origin, 36 third preparatory origin, and 42 fourth year freshman origin chemistry education students of Dilla University. The freshman origin groups of students stands for the old curriculum students who attended their freshman courses in the colleges/or Universities. However third year preparatory origin students stands for the new curriculum students who attended their freshman/introductory chemistry courses in their two years stay at different preparatory schools.

For ease of analysis, preparatory origin group of students were grouped and recognized as a third year level students by counting their two years stay at preparatory schools as equivalent to one year stay at university and their two year study in the university. While this study was conducted both the third year preparatory and freshman origin students were at the same year level and attending the same chemistry courses.

By disproportionate stratified random sampling technique 60 subjects were selected from each stratum. That is 56 % (N=20) third year preparatory origin students, 43 %(N=20) third year freshman origin students and 48% (N=20) fourth year freshman origin students. From the total of four female students: two from third year and two from fourth year female students, three of them participated by their consent.

The purpose of this study was to explore if there is a problem solving ability difference among chemistry education students due to student year level and origin. As problem solving behavior is related to self efficacy beliefs and knowledge structure, two different corresponding instruments were designed to measure these variables.

This study used chemistry tasks to measure accessible and problem specific knowledge structure and problem solving behavior of students. According to Myer in Kirkley (14) problem solving is cognitive but it can be inferred from behavior and its result that lead to a solution. For instance knowledge is stored in mind in several forms: words and pictures for example. Moreover, Leithwood, Steinback, and Raum (15) discuss that knowledge goes beyond purely cognitive content implied by the term. This implicitly infers that knowledge structure and problem solving performance can be implied when the solver is working on tasks.

The tasks designed to illicit chemical knowledge structure and problem solving performance of students is closely related to everyday life and include one algorithmic and five conceptual problems (Appendix). The tasks were designed from topics in the introductory courses selected by the following criteria:

a. The topics are taught for target groups (i.e. third and fourth year chemistry education students).
b. Common topic to the target group and are identified by mastery objectives to be achieved
c. The topics are more closely related to every day life.

Moreover, each of the problems was designed to exhibit problem solving behavior and elicits propositional and procedural knowledge required in solving the problems.

Initially four algorithmic and seven conceptual problems were designed. Then the problems have been evaluated by chemistry lecturers and master students using the following criteria:

a. Stated in clear and simple languages
b. Authentic and practically important and application problems
c. Appealing to all three groups of students
d. Solvable using a variety of solution strategies; and
e. The difficulty of the problems in terms of the number of principles required to solve

And then based on the comments received from one analytical and one inorganic chemistry lecturers of Dilla University, and one analytical and one environmental chemistry master students of Addis Ababa University the instruments were revised and reduced in to six. The tasks/problems were integrated with instructions that demand students to set goals before engaging in solution process, to write the conditions (givens), constraints in solving and then to write every step that the solver used to solve each problem. Finally the six problems which met the criteria were administered. In addition to the instructions provided in print form, verbal instructions were given on how to work on each problem.

The numerical data collected on problem specific and easily accessible knowledge structure (ASPK) and problem solving performance (PSB) are analyzed using mean, standard deviations; two-sample independent t-test, one-way ANOVA and post hoc tukey test by using statistical analysis software origin 7. Two-sample independent t-test, one-way ANOVA and post hoc tukey test statistical techniques were applied to see if there were a statistical significance difference observed in APSK and PBS among third year students, third year preparatory and freshman origin students, and fourth years students.

Task analysis is one of the important steps of problem solving investigation. Sugrue (9) notes that most problems solving investigations and reasoning begins with a task analysis. Task analysis is not a formal and standard set of procedures but the type of analysis will vary depending on the theoretical framework of the researcher as well as the extent and sophistication of the available research and theory. However, outcome of this analysis is an explicit statement of all cognitive activity that occurs from initial presentation and final solution of a problem.

Therefore, in view of this idea, in order to examine status of cognitive components of problem solving ability: 1) problem solving behavior/performance (PSB), and 2) the accessible problem specific knowledge structure (APSK) of chemistry education students on the task were analyzed using scoring grid (see appendix B). The scoring grid were developed from the literature, such as Sugrue (9). The scoring grid for each problem ranges from 0 to 4. The total score of each student's performance on the task is obtained by adding the scores obtained for each task/problem. Therefore, the total scores of each student's PSB and APSK on the task/problem could range from 0 to 24. Based on the scoring model explanations students were classed into the following three problem solving performance (PSB) categories:

	Category of problem solving behavior	Total score on the task/problem
1	Poor problem solvers	[0,6]
2	Moderate problem solvers	(6,18]
3	Successful problem solvers	(18,24]

Similarly using the scoring model explanations used students were classed into the following three problem specific and easily accessible chemistry knowledge structure (APSK) categories:

S. No.	Category of students APSK used for solving the task/problem	Total score on the task/problem
1	No APSK or fragmented APSK with specific misconception	[0,6]
2	Partial and Fragmented APSK	(6,18]
3	Active and well integrated APSK	(18,24]

RESULTS AND DISCUSSIONS

Demographic descriptions

60 subjects were participated in the study: 57 male and 3 female. Out of these, 40 were third year students (i.e. 20 preparatory and 20 freshman origins) and 20 were fourth year students.

Table 1: Demographic data

Sample characteristics		Frequency (N)	Percent (%)
Gender	Female	3	5
	Male	57	95
Year level and origin	a. Third year freshman origin	20	43
	b. Third year preparatory origin	20	56
	c. Fourth year freshman origin	20	48
Tasks are from chemistry topics we have learned already	a. Yes	57	95
	b. No	3	5

As it can be seen from table 1, 3 of the 57 participants responded that the tasks were not from topics they were being taught. This implied that the knowledge component of problem solving can be suffered for only few groups of students.

1. *Does the curriculum reform that shift an introductory university course from university into preparatory schools have an impact on chemistry education students' problem solving performance in chemistry*?

Null hypothesis (H_0): There is no statistically significantly different problem solving performance in chemistry among third year freshman origin, preparatory origin and fourth year freshman origin chemistry education students. H_0: $\mu_1 = \mu_2 = \mu_3$

Alternative hypothesis (H1): There is statistically significantly different problem solving performance in chemistry among third year freshman origin, preparatory origin and fourth year freshman origin chemistry education students.

H1: $\mu 1 \neq \mu 2 \neq \mu 3$, or $\mu 1 \neq \mu 3$, or $\mu 1 \neq \mu 2$, or $\mu 2 \neq \mu 3$.

A one-way ANOVA comparison test on μ_1, μ_2, and μ_3 shows that the population means were significantly different from the test difference (0), $F(2,57)=13.36$, $p=4.57$, at $\alpha=0.05$ level. This result indicates that students' origin has a significant effect on problem solving performance. The mean values for problem solving performance of fourth year freshman origin (M3), third year freshman origin (M2), and third year preparatory origin students (M1) indicate that the problem solving performance is higher for freshman origin students than for preparatory origin students ($M_3 = 12.07$, $SD_3 = 4.05$; $M_2 = 12.79$, $SD_2 = 4.19$; $M_1 = 5.36$, $SD_1 = 3.07$).

In order to locate the significantly different population means, a post hoc multiple comparison, Tukey test was applied.

Table 2: Results of means comparison using Tukey at test $\alpha=0.05$ level

Students origin and year level	Mean(M)	Difference between means	Simultaneous confidence intervals		Significant at $\alpha=0.05$ level
			Lower level	Upper level	
4th year 3rd year preparatory origin 3rd year freshman origin	12.07				
	5.36	6.71	2.91	10.51	Yes
	12.79	0.714	4.28	2.85	No
3rd year preparatory origin 3rd year freshman origin	5.36 12.79	-7.42	11.22	-3.62	Yes

As it can be seen from table 2, the means comparison using Tukey test at α=0.05 level showed that there was a significant difference between the population means of third year preparatory origin (μ_1) and mean of third year freshman origin (μ_2); the mean of third year preparatory origin (μ_1) and mean (μ_3) of fourth year freshman origin students. In short $\mu_1 \neq \mu_2$ and $\mu_1 \neq \mu_3$ are significantly different at α=0.05. However, there was not statistically significant difference between mean of third year freshman origin students (μ_2) and mean of fourth year freshman origin students (μ_3) , at α=0.05. The result indicates that both freshman origin students' (i.e. fourth year and third year) problem solving performance is significantly different from preparatory origin students' problem solving performance. But third year freshman and fourth freshman year students' problem solving performances do not differ significantly. This result shows the possibility that the overall difference in problem solving performance in chemistry is because of students' origin (i.e. due to the shift of university introductory courses in the old curriculum in to preparatory school levels in the new curriculum).

2. *Do students year level has an impact on chemistry education students' problem solving performance in chemistry?*

Null hypothesis (H_0): There is no statistically significantly different problem solving performance in chemistry among third year and fourth year freshman chemistry education students. H_0: $\mu_4 = \mu_3$

Alternative hypothesis (H_1): There is statistically significantly different problem solving performance in chemistry among third year and fourth year freshman chemistry education students. H_0: $\mu_4 \neq \mu_3$

An independent two sample t-test at α=0.05 was used to determine if there would be any significant difference between problem solving means of third and fourth year students.

Table 3: Two sample independent t-test on problem solving means of third and fourth year chemistry education students (α=0.05)

Year level	N	Mean(M)	Standard deviation (SD)	Standard error (SE)	t	p-value
Fourth year	20	12.07	4.05	1.08	1.57	0.125
Third year	40	9.52	5.25	1.05		
Mean difference		2.55				

As it can be seen from table 3, the sample mean (M_3) and standard deviation (SD_3) of problems solving score of fourth year students was M_3= 12.07, SD_3 = 4.05 and mean (M_4) and standard deviation (SD_4) of third year students was M_4 = 9.52, SD_4= 5.25.

A two sample independent t-test shows that there is not statistically significant difference between the population means of fourth year and third year students from the test difference, (μ_4 - μ_3 = 0),(t(58) =1.57, p=0.125). This result indicates that year level has not a significantly effect on students' problem solving performance. Studies show that basic problem specific domain knowledge determines successful problem solving (7, 10, 12). However, this implies that year level in both old and new curriculum is less likely to improve students' problem specific domain knowledge structure.

3. *Does the curriculum reform that shifted an introductory university courses, from university to preparatory schools has an impact on chemistry education students' problem specific and easily accessible knowledge structure?*

Null hypothesis (H_0): There is no statistically significance difference in problem specific and easily accessible knowledge structure among third year preparatory origin, third year freshman origin and fourth year freshman origin chemistry education students. H_0: $\mu_1 = \mu_2 = \mu_3$

Alternative hypothesis (H_1): There is statistically significance difference in problem specific and easily accessible knowledge structure among third year preparatory origin, third year freshman origin and fourth year freshman origin chemistry education students. H_1: $\mu_1 \neq \mu_2 \neq \mu_3$, or $\mu_1 \neq \mu_3$, or $\mu_1 \neq \mu_2$, or $\mu_2 \neq \mu_3$.

A one-way ANOVA comparison test on μ_1, μ_2, and μ_3 shows that the population means were significantly different than the test difference (0), $F(2,57)=11.64$, $p=1.26$, at $\alpha=0.05$ level. This result indicates that students' origin has a significant effect on accessible and problem specific knowledge structure of students. The means value for accessible and problem specific knowledge structure of fourth year freshman origin (M_3), third year freshman origin (M_2), and third year preparatory origin students (M_1) indicates that the accessible and problem specific knowledge structure is higher for freshman origin students than for preparatory origin students ($M_3 = 15.79$, $SD_3 = 4.35$; $M_2 = 16.12$, $SD_2 = 2.49$; $M_1 = 10.45$, $SD_1 = 2.25$).

To determine/locate statistically significant different means of the population parameters Tukey test was applied at $\alpha=0.05$.

Table 4: Third year preparatory origin, third year freshman origin, and fourth year students usable and problem specific knowledge structure mean comparisons, ($\alpha=0.05$)

Students origin and year level	Mean (M)	Difference between means	Simultaneous confidence intervals		Significant at $\alpha=0.05$ level
			Lower level	Upper level	
4th year 3rd year preparatory origin 3rd year freshman origin	15.79				
	10.43	5.33	2.14	8.52	Yes
	16.21	-0.429	-3.42	2.56	No
3rd year preparatory origin 3rd year freshman origin	10.45 16.21	-5.76	-8.95	-2.57	Yes

As it can be read from table 4, Tukey test indicated that there is a statistically significant difference between the population means of fourth year freshman origin and third year preparatory origin students; third year freshman origin and third year preparatory origin students. In short $\mu_3 \neq \mu_1$ and $\mu_2 \neq \mu_1$ are significantly different at α=0.05. However, there was not statistically significant difference between the means of fourth year freshman origin students (μ_3) and third year freshman origin students (μ_2), at α=0.05.

This result indicates that both freshman origin students' (i.e. fourth year and third year) problem specific and easily accessible chemistry knowledge structure is significantly different from preparatory origin students' problem specific and easily accessible chemistry knowledge structure. But freshman origin (i.e. third year freshman origin, fourth year freshman origin) students' problem specific and easily accessible chemistry knowledge structure do not differ significantly. This result shows the possibility that the overall significant difference in problem specific and easily accessible chemistry knowledge structure is more probable to be due to students' origin (i.e. the shift of university introductory courses of the old curriculum into preparatory schools of the new curriculum).

4. *Do students year level has an impact on chemistry education students' problem specific and easily accessible knowledge structure?*

Null hypothesis (H_0): There is no statistically significance difference in problem specific and easily accessible knowledge structure between third year and fourth year chemistry education students. H_0: $\mu_4 = \mu_3$

Alternative hypothesis (H_1): There is statistically significance difference in problem specific and easily accessible knowledge structure between third and fourth year chemistry education students. H_0: $\mu_4 \neq \mu_3$

An independent two sample t-test at α=0.05 was used to compare if there would be any statistically significant difference between problem specific and easily accessible knowledge structure means of third and fourth year students.

Table 5: Two sample independent t-test and summary statistics on fourth and third year students' APSK

Year level	N	Mean	SD	SE	t	p-value
Third year	40	13.68	3.74	0.75	-1.59	0.120
Fourth year	20	15.79	4.35	1.16		
Mean difference		-2.11				

As can be seen above, the mean (M_3) and standard deviation (SD_3) of problem specific and easily accessible knowledge structure score of fourth students was M_3 = 15.79, SD_3 = 4.35 and mean (M_4) and standard deviation (SD_4) of third year students was M_4 = 13.68, SD_4= 3.74.

A two sample independent t-test shows that there is not statistically significant difference between the means of fourth and third year students from the test difference (μ_4 - μ_3 = 0), t (58) =1.57, p=0.125). This result indicates that year level has no significant effect on students' problem specific and easily accessible chemistry knowledge structure on topics being taught.

CONCLUSIONS

From the current study the researcher concluded that

1. The curriculum reform that moved university courses into preparatory schools has failed to achieve the objective of teacher education that aims to produces successful problem solvers.

2. The new curriculum has not been as impactful as the old curriculum that offered introductory courses in the first year university study in developing well integrated problem and domain specific chemical knowledge among chemistry education students.
3. The problem solving ability of chemistry education students' is more likely to be affected by curriculum reform than the number and year level of students attended in the university.

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APPENDICES

I. Task from some selected content areas of chemistry

Instruction: dear student there are six chemistry problems designed for you. Please attempt each of the problems. The problem(s) might have come across you in your everyday life. While you are attempting to solve each of the problems, do not use separate paper, please. Before you are going to engage in solving the problems, please restate each of them what it asks you in your own words. Your answer will remain strictly confidential and WILL NOT affect your grade.

1. If a reaction that is exothermic can be controlled catalytically, then by regulating the amount of the catalyst available perhaps the rate of release of heat from the reaction can be regulated. How? Justify your answer.
2. Assume you are living in a rural area where there is no electricity and refrigerator, but you want to supply a coca cola below the surrounding temperature. How can you cool this soft drink? Suggest methods and explains every of your steps.
3. Rain water in Norway and German tastes sour. What do you think the reason? What possible solution that doesn't harm their economy would you suggest to reduce the problem?
4. The salinity of a solution is defined as the grams of total salt per kilogram of solution. An agricultural chemist uses a solution whose salinity is 36.0 g/kg to test the irrigating farm land with high salinity river water. The two solutes are NaCl and Mg_2SO_4, and there are twice as many moles of NaCl as Mg_2SO_4. What masses of NaCl and Mg_2SO_4 are contained in 1.00 kg of the solution?

5. Suppose you are in need of AgCl, but only crystals of AgNO3 and NaCl are available in your chemical store. How would you obtain AgCl? Propose ways with detail explanations.
6. Suppose, while you are cooking food with high nutritive value which can only boil at high temperature, water would bubbled and finished up before the food is well cooked. What could be the possible reason? Propose your possible procedure to cook it sufficiently.

II. Scoring grid for problem solving performance (task analysis)

weight	criteria	attributes
0	No correct solution	- Blank space, I don't know, - Incorrect understanding of the problem with in correct solution, determine the goal state constraints to reach to the solution
1	Partially correct with some mistakes	- Correct understanding (mental representation of the problem with incorrect solution)
2	Partially correct solution	- Correct understanding of the problem and solving some components of the problem, such as using logical methods, appropriately applying the concepts and principles.
3	Correctly solving the problem but with incomplete correct solution	- Correct understanding of the problem, - Using logical methods of attacking the problem, - Applying the relevant knowledge structure and algorism to the problem but not completed.
4	Successfully solving the problem	- Correct understanding of the problem, - using correct and logical methods of attacking the problem - using relevant knowledge structure and algorithms to the problem, giving the ultimate solution of the problem

III. Scoring grid for problem specific and easily accessible chemistry knowledge structure exhibited on chemistry tasks

weight	criteria	attributes
0	No accessible and problem related knowledge structure to solve it	- Blank , I don't know - Incorrect knowledge: wrong understanding of concepts and principles - I do not understand
1	Partially accessible problem related knowledge structure, but with some misconceptions	- Knowledge of general problem (task) related concepts, principles but with some misconceptions - Lacks problem specific concepts to directly attack the problem
2	Partially accessible knowledge structure related to the problem/task	- General knowledge of concepts and principles but no link is made between knowledge and the problem. - The concepts and principles were fragmented, lacks problem specific concepts and principles to directly attack the problem
3	Accessible knowledge structure but with some deficit to successfully solve the problem	- Knowledge of general concepts and principles related to the task - The links made between concepts and principles with the problem/task - Knowledge of some problem specific concepts and principles to directly attack the problem but with some fragments
4	Active and well integrated knowledge structure to successfully solve the problem	- General and specific concepts directly related to the problem - Integration of concepts and principles with concepts involved in the problem - Knowledge of correct algorithms correctly solves the problem