(evidence found in 90% of the cases for at least one of the problems). Also, these papers show evidence of a mathematical formulation of the physics principles involved (evidence found in almost 90% of the cases for at least one of the problems). Subjects in this group do not show evidence of a qualitative description stage in their written solutions (except for a 10% minority, who explicitly show this stage for one of the problems). It is noteworthy that no evidence was found either for the explicit mention of physics principles or for the control of results.

CONCLUSIONS AND PERSPECTIVE

The values found for the indicators in each of the groups of subjects analyzed were found to be internally consistent. This finding can be considered to support the model adopted for the problem solving process. Also, the instruments designed for the study are found to be internally coherent. The following results found in each group serve as a basis for this conclusion.

Subjects in classroom A demonstrate that they go through a stage where they make a qualitative description of the situation. These subjects explicitly state the physical laws and principles used in the solving procedure and are able to check the consistency of the results they obtain. In terms of the theory, these subjects can be assumed to have built a situation model that enables them to incorporate the physical principles, formally expressed in equations, in a meaningful way.

Results related to classroom B do not show evidence of a qualitative description stage. In this group, equations are found to be written without an accompanying statement of the physical laws they represent. Therefore, these laws cannot be considered to have been meaningfully incorporated into the subjects' representations. At the same time, the subjects in this group do not appear to be able to check the results they obtain. These two characteristics occurring in the same group of students are in agreement with the predictions for the model adopted.

Regarding the central purpose of this study, the following conclusions can be drawn about the relationships between the teaching strategies used in the classroom and the students' problem solving performance.

In classroom A, the teacher explicitly and consistently insisted on the importance of recognizing the physical principles involved in the situation analyzed. The problem was usually re-stated and the meaning of the mathematical equations used was discussed. The teacher in classroom B focused the attention on the generation of the mathematical equations necessary to obtain the solution sought. The data collected on the students' performance show signs of these different teaching strategies and a correspondence can be inferred between the teaching strategy and the problem solving characteristics in each group.

As described above, different instructional models used in classrooms have an influence on the characteristics of the students' performance in problem solving activities. Students learn a problem solving model, even if it is not taught explicitly. The present results illustrate the relevance that teaching strategies used for physics problem solving have for the students' learning process. In this sense, the perspective is promising for the continued study of teaching strategies that could prove to be effective in improving student performance in the task of physics problem solving.

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The effects of pair problem solving technique incorporating Polya's problem solving strategy on undergraduate students' performance in chemistry

Los efectos de aplicación del método de resolución de problemas en pares y estrategia de Polya en el desempeño de los estudiantes universitarios en química

Ibrahim Bilgin

Department of Elementary Education, Abant Izzet Baysal University, 14280-Bolu, Turkey, bilgin64@yahoo.com

Abstract

The purpose of this study was to investigate the effects of pair problem solving technique incorporating Polya's problem solving strategy on undergraduate students' performance in conceptual and algorithmic questions in chemistry. The subjects of this study were 89 students enrolled from two first year chemistry classes. The experimental group was a class of 44 students who received pair problem solving technique incorporating Polya's problem solving strategy and the control group was a class of 45 students who received only Polya's problem solving strategy. Students' achievement of conceptual and algorithmic questions in chemistry was measured using as post-tests, Conceptual Chemistry Question Test (CCQT) and Algorithmic Chemistry Question Test (ACQT). Test of Logical Thinking (TOLT) was used as a covariate in this study. The results of Analysis of Covariance (ANCOVA) showed that students in experimental group had significantly better performance on both conceptual and algorithmic questions in chemistry. The results of this study for students' problem solving performance are discussed.

Key words: *problem solving, chemistry, conceptual and algorithmic questions, pair problem solving technique, Polya*

Resumen

En este estudio se investigan los efectos del método de resolución de problemas en pares, junto con el método de Polya, en química universitaria con la participación de 89 estudiantes inscritos en dos cursos de la química general. El grupo experimental con 44 alumnos recibieron la metodología propuesta y el grupo de control de 45 estudiantes trabajaron solamente con estrategia de Polya. El logro de los estudiantes en los aspectos conceptual y algorítmico en química fue medida después del estudio usando la prueba conceptual (CCQT) y la prueba algorítmica (ACQT); la prueba de pensamiento lógico (TOLT) fue usado adicionalmente. El resultado del análisis estadístico (ANCOVA) demostró que los estudiantes del grupo experimental tuvieron el mejor desempeño en aspectos conceptuales y algorítmicos en química. El resultado de este estudio del desempeño de estudiantes en la solución de problemas se está discutiendo.

Palabras clave: *resolución de problemas, química, preguntas conceptuales y algorítmicas, resolución en pares, Polya.*

INTRODUCTION

Problem solving has always constituted a significant part of the science curriculum and has been regarded as a valuable assessment tool by educators. (White, 1978; Weinstein, *et al.*, 1980; Linn, 1987; Breen, *et al.*,1994; Chen, *et al.*, 2000; Hass and Parkay, 1993). The term problem solving is defined by Pizzini, *et al.* (1989) as a method of learning as well as an outcome of learning, by Gagne (1977), as a thinking process when the learner needs to use previous learned concept to solve a novel problem. Reid and Yang (2002) stated that inappropriate chemical knowledge prevents students' problem solving ability in chemistry. Anderson (1990) described student knowledge in terms of declarative and procedural knowledge. Declarative knowledge refers to what person knows about subjects which include facts, concepts and principles, while procedural knowledge refers to skills and procedures in utilizing factual knowledge in analysis, synthesis, and process of problem solution. Chiu (2001) stated that "conceptual understanding refers to declarative knowledge while algorithmic problem solving skills refer to procedural knowledge" (p. 21) and problem solving requires declarative and procedural knowledge.

There are different approaches in the literature to identify whether students are algorithmic or conceptual problem solvers in chemistry. The most common one is asking students pairs of algorithmic and conceptual questions. Sawrey (1990), Nakhleh and Mitchell (1993), Mason, *et al.* (1997), Niaz (1995), and Chiu (2001) asked students two questions related to the same topic. One question requires conceptual understanding while the other requires algorithmic skills. A second approach is problem solving networks in chemistry. Frazer and Sleet (1984) and Ashmore, *et al.* (1979) asked students to solve one main problem and its related sub-problems. In this approach, students who cannot solve the main problem but who can solve all its component of sub-problems are called algorithmic problem solver; students who can solve the main problem and its related sub-problems are called conceptual problem solver. A third approach uses a test which includes M-Demand of different items of content of general chemistry topics. Tsaparlis, *et al.* (1998), Niaz (1988), Niaz (1987), and Niaz (1989) used a test which includes different numbers of steps to solve problems. In this approach, students who can solve one, two or three-step problems are called algorithmic problem solvers and students who can solve four or more-step problems are called conceptual problem solvers. Johnstone (2001) also reported that students who can solve 'familiar problem' are called algorithmic problem solvers and students who can solve 'unfamiliar problem' are called conceptual problem solvers. There are two main findings of the above-mentioned research: (1) students find difficulties for solving conceptual problems in chemistry, and (2) the ability of students for solving algorithmic problems is not the major factor in predicting their success on solving conceptual problems. According to Johnstone (2001), the most common obstacle to problem solving is the lack of conceptual understanding of subjects when students try to solve novel problems. Therefore, conceptual understanding is important. Science instruction, chemistry instruction in particular, should motivate students to construct a conceptual understanding of scientific phenomena rather than applying algorithms to problems (Gabel and Bunce, 1994).

One of the goals of science education is to develop learners' ability to acquire knowledge in specific subjects and to improve their problem solving skills. Problem solving requires overcoming all impediments in reaching an objective. Many researchers showed that problem solving is one of the most important goals and desired outcomes of learning chemistry (Pizzini, *et al.*, 1989; Herron, 1996; Gabel and Bunce, 1994). Hence, it is essential to help students to understand the pre-requisite knowledge and skills for problem solving and avoid applying memorized skills in rote fashion. Traditionally, chemistry instruction focuses on formal, lecture-oriented teaching and underestimates students' understanding of underlying concepts. Instructor presents facts and equations to be memorized (Bodner, as cited in Zoller, 1993; Swift, Gooding and Swift, 1989). This type of teaching does not enhance the development of higher-order cognitive skills; instead, it promotes lower-order cognitive skills which can be defined as abilities to recall information or simple application of known theory to familiar situations by means of algorithmic processes (Zoller, 1999). Therefore, students get the information without processing it; in other words, they cannot apply their higher-order cognitive skills.

Problem solving skills are promoted by providing a rich environment, which has potential for exploration and encourages students to reflect on their actions (Hass and Parkay, 1993). Orlik and Mikhailov (2001), one of the studies that emphasized providing a rich environment for students, investigated effects of visual algorithmic-schemas for solving chemistry problems on 10^{th} grade students' performance on "the mass-mol and mol-mass calculation, writing the formula in the base of the percentage of elements and finding the percentage of elements in the formula and in other direct and inverse numerical problems in chemistry". They found that this approach increased students' problem solving skills, because this approach help students at three levels: analysing the content of the problem at the beginning of the problem solving situation, assisting in final analysis of results, and finding correction of errors. In addition, the teacher uses visual algorithmic-schemas as an effective tool to "show students the important relations between substantive knowledge of chemical theories and concepts and problem solving abilities".

Polya (1957) systematized the efficient problem solving process as four stages: i) understanding the problem, ii) devising a plan, iii) carrying out the plan, and iv) looking back. *Understanding the problem* is the first and the most necessary step for understanding the aim and requirements of the problem before trying to solve it. Many studies emphasize students' understanding of the problem as the most crucial step in solving the problem. It is important to establish a classroom environment in which language is being used, shared, and understood by students. "What is given in the problem?", "What are the data?", and "what are the conditions?" are questions that students should ask to themselves before devising plan. The second stage is *devising a plan*. After defining what is required, using all information and conditions may lead to finding a technique or a method to solve the problem. At this step, students always have to keep in mind what they want to find and which units they need to implement the plan. The third stage is *carrying out the plan*. After a plan is devised, it must be carried out systematically to check for a solution. At this step, students may use different strategies for solving the problem. Students should carry out each step carefully before moving to the next step. Common questions that teachers should ask are as follows: "Is the answer sensible?" "Can you see that this step is correct?", and "Can you prove that this step is correct?". The last stage is *looking back*. It is very important to revise and to reflect on the method of how problems are solved and strategies are employed for subsequent use. After solving the problem, it can be very fruitful that students rethink the whole solution process. Teacher might ask the following questions to help them reflect on their findings: "Can you check the result(s)?", "Can you justfy your argument(s)?", and "Can you use the result or the method to solve some other problems?".

There is no one proper approach that teacher can use for any subject matter. Different subjects require different kinds of approaches. If teachers are aware of different aspects of the subject matter, they can make adjustments based on given guidelines. Problem solving task has significant effects on problem solving performance. It is very important to devise appropriate tasks to relay certain concepts and accomplish effective teaching. Some tasks may also be closely monitored to get or to provide feedback about students' actions. The main advantage of this approach is after enable students to think systematically, employ implicit planning and reflect explicitly on their problem solving behaviors.

Currently, the conceptual understanding of chemistry by students is an important issue. Berquisit and Heikkinen (1990) indicated that it is important to provide students with opportunities to verbalize their ideas, and thus, to promote students' conceptual understanding and remediate their misapplication of concepts. As pointed out by many research studies, cooperative learning provides an instructional learning environment in which students discuss the material, share ideas, listen and consider ideas of others, and clarify their thinking through verbal interaction with each other (Webb, 1982; Chen, 1994; Watson and Marshall, 1995; Lonning, 1993). Hence, it is necessary to develop new learning environments incorporating instructional strategies to enhance the learning of abstract science concepts to develop learners' problem solving skills.

Pair problem solving technique is an effective way of helping students think about the problem and gives them feedback on what is understood and what is still unclear in their own problem solving. Herron (1996) and Whimbey and Lochhead (1986) emphasized its effectiveness. In this technique, Herron (1996) reported that "one student acts as the problem solver while the other acts as a checker. The problem solver reads the problem aloud and continues to talk while solving the problem. The checker monitors what is said and may stop the solver and ask for clarification when a procedure is not clear" (p. 85).

Pate, *et al.* (2004) and Johnson and Chung (1999) investigated the effects of thinking aloud pair problem solving performance of undergraduate agriculture students in a popular technology course and found that students who participated in pair problem solving groups were more successful at troubleshooting engine faults than were students in work alone control groups. According to Johnson and Chung (1999), pair problem solving technique increases students' problem solving success. PESTEL (1993) used thinking aloud problem solving in college chemistry and found that thinking aloud problem solving class get fewer problems completely right, but also they get fewer problems completely wrong.

METHOD

Purpose

The purpose of this study was to determine effects of pair problem solving technique incorporating Polya's problem solving strategy on undergraduate students' performance of conceptual and algorithmic questions in chemistry. Therefore, this study was designed to investigate the following research questions: (1) Is there a significant difference between effects of pair problem solving technique incorporating Polya's problem solving strategy and using only Polya's problem solving strategy on undergraduate students' conceptual questions in chemistry when their Logical Thinking (TOLT) scores are used as a covariate? (2) Is there a significant difference between effects of pair problem solving technique incorporating Polya's problem solving strategy and using only Polya's problem solving strategy on students' algorithmic questions in chemistry when their TOLT scores are used as a covariate?

The Sample

The sample of this study were 89 students (17-19 year olds; mean=18,4) enrolled from two classes of general chemistry course offered to the first year students by the Department of Elementary Education at Abant Izzet baysal University in Turkey. General chemistry course is a compulsory course for all students to attend 3 hour lecture per-week in first year spring semester at the Department of Elementary Education. This course covers the nature of the matter, atomic models, chemical bonds, moles, chemical reactions, solutions, molarity and gas concepts. One class was randomly assigned to the experimental group (n=44; 19 male and 25 fmale) while the other group formed the control group (n=45; 21 male and 24 fmale). Students in the experimental group were instructed with pair problem solving technique incorporating Polya's problem solving strategy while students in control group were instructed with Polya's problem solving strategy. All students were taught by the same instructor. During a seven-week period, each group received equal amount of instructional time and was provided with the same materials.

Instrument

In order to address research questions asked in this study, Conceptual and Algorithmic Questions Tests and Test of Logical Thinking were used. Conceptual and Algorithmic Questions Test is divided into two parts each of which has 6 items. The part which has six conceptual questions is called as Conceptual Chemistry Question Test (CCQT), and the part which has six algorithmic questions is called as Algorithmic Chemistry Question Test (ACQT). All of the test items were taken from previous studies (NURRENBERN and PICKERING (1987), NAKHLEH and MITCHELL (1993), NIAZ (1995), SAWREY (1990), and CHIU (2001). All of the test items were multiple-choice, except items 6A and 6B. Each of the correct answers were scored 1 point. The Cronbach's alpha reliability coefficient of the test was found to be 0.65 for conceptual questions and 0.75 for algorithmic questions. The test is given in Appendix A.

Test of Logical Thinking (TOLT) was developed by TOBIN and CAPIE (1980). It is a two-tier multiple-choice instrument designed to assess cognitive development of students. It contains ten items. Students were supposed to respond correctly to both parts of an item to get a credit from it. An item was marked as correct only if both the answer and the reason were correct. The Cronbach's alpha reliability coefficient of the logical thinking skills test was found to be 0.74.

Treatment

This study was conducted over a 7-week period. In this study, there were two groups of students: one experimental group and one control group, instructed by the same instructor. Experimental and control groups were given TOLT as a pre-test at the beginning of the study and CCQT and ACQT as a post-test after instruction. One week before the treatment, the instructor was trained about Polya's problem solving strategy, pair problem solving technique, and the researcher's prepared materials. It was explained to him that special emphasis was given to assigning students in pairs and incorporating pair problem solving technique into Polya's problem solving strategy. While the researcher prepared problem solutions according to Polya's problem solving strategy, he benefited mostly from Holt Chemistry (2004). In the regular classroom instruction, the instructor taught related concepts throughout the lecture and the whole class discussions.

Before the treatment, students in experimental and control groups were trained about Polya's problem solving strategy and a worksheet which includes detailed descriptions of Polya's problem solving steps distributed to all students. Students in experimental group were also trained how the pair problem solving technique is incorporated with Polya's problem solving strategy. A worksheet, which explains problem solver and checker responsibility during the problem solving, was given to students. Students in experimental group were assigned as pairs and each pair students was included one higher score student and one lower score student based on their test of logical thinking results.

After the instructor taught each part of the regular classroom subjects in experimental and control groups, he presented a problem relating to concepts which are solved based on Polya's problem solving steps and explained each step to the whole class. In the control group, after the instructor's explanations, each of the students was given two problems on the worksheet to solve problems individually based on Polya's problem solving steps. In the experimental group, after the instructor's explanations, each pair of students was given the same problems as control group on the worksheet, but were asked to solve problems incorporating pair problem solving technique with Polya's problem solving steps. Students who have low scores on test of logical thinking first act as problem solvers, and students who have high scores on test of logical thinking first act as checkers. Problem solver reads the problem aloud, follows each of Polya's problem solving steps, and writes each steps' requirement on the proper place on the worksheet to solve the problem. Problem checker thinks along with the solver and does not directly participate in the problem solving, but encourages the solver to verbalize his or her thoughts by frequently asking for in-depth explanations. When pairs completed their works for each question, the instructor asked some pairs to explain their findings for the whole classroom. During this period, the instructor helped students having difficulty in finding relationships between concepts. After each problem is solved, the problem solver and the checker roles are switched.

RESULTS

Descriptive statistics of TOLT, CCQT, and ACQT for experimental and control groups were found and given in Table I, II and III, respectively.

Table I

Descriptive statistics of TOLT scores for experimental and control groups

Group	n	$\bar{X}$	SD	Mode	Median	Min-Max
CG	45	5,978	2,641	6,000	6,000	1-10
EG	44	6,000	2,215	6,000	6,000	2-10

It is seen that students' mean scores of TOLT were similar for experimental and control groups. Prior to treatment, an independent t-test was employed to determine whether a statistically significant mean difference existed between control and experimental groups with respect to TOLT scores. No statistically significant mean difference between the two groups was found with respect to TOLT scores ($t = 0.129$, $df = 87$, $p > 0.05$), indicating that students in experimental and control groups were similar for this variable.

Table II

Descriptive statistics of ACQT scores for experimental and control groups

Group	n	$\bar{X}$	SD	Mode	Median	Min-Max
CG	45	3,333	1,5023	4,000	3,000	1-6
EG	44	4,659	1,160	6,000	5,000	3-6

Table III

Descriptive statistics of CCQT scores for experimental and control groups

Group	n	$\bar{X}$	SD	Mode	Median	Min-Max
CG	45	1,711	1,255	2,00	2,000	0-5
EG	44	3,114	1,224	4,00	3,000	0-5

It can be observed from table II and III that students in experimental group have higher performance on ACQT and CCQT scores than students in control group. Also, students' performance in experimental and control groups on ACQT scores was higher than their CCQT scores.

In order to investigate effects of pair problem solving technique incorporating Polya's problem solving strategy, ANCOVA was run separately on post-ACQT and CCQT and TOLT scores used as a covariate to statistically control initial group differences. Before conducting the analysis of ANCOVA, the covariate was examined. According to Weinfurt (1995), covariate should be used only if there is a statistically significant linear relationship between the covariate and dependent variables. Therefore, the condition has been tested with Pearson correlation between predetermined confounding variable (TOLT) and each dependent variables, ACQT and CCQT. TOLT scores have significant correlation with ACQT score ($r = +0.787$, $N = 89$, $p < 0.01$) and CCQT score ($r = +0.442$, $N = 89$, $p < 0.01$). Hence, TOLT scores were used as a covariate.

Levene's test was used to check the assumption that error variance of dependent variables is equal across experimental and control groups. All significant values for dependent variables, ACQT scores ($F(1,87) = 1,205$; $p>0.05$) and CCQT scores ($F(1,87) = 2,000$; $p > 0.05$), were greater than 0.05, which means that equality of variances assumption was not violated.

Table IV contains the summary of ANCOVA comparing the mean scores of the performance of students both experimental and control groups with respect to post-ACQT scores.

Table IV

Summary of ANCOVA comparing the mean post-ACQT scores of students in experimental and control groups

Sources	df	Mean square	F	P
Treatment	1	37.89	65.289	0.000*
TOLT	1	109.98	189.528	0.000*
Error	86	0.580		

*Significant at $p < 0.05$.

The analysis showed that students' TOLT scores have significant effect on their post-ACQT scores ($F(1, 86) = 189.528$, $p < 0.05$). The results also indicated significant treatment effect $F(1, 86) = 65.289$, $p < 0.05$. The students in the experimental group who were instructed in pair problem solving technique incorporating with Polya's problem solving strategy demonstrated better performance (adjusted mean = 4.649) on algorithmic questions in chemistry over the control group students who were instructed in only Polya's problem solving strategy (adjusted mean = 3.344).

Table V contains the summary of ANCOVA comparing the mean scores of the performance of students both experimental and control groups with respect to post-CCQT scores.

Table V. Summary of ANCOVA comparing the mean post-CCQT scores of students in experimental and control groups

Sources	df	Mean square	F	P
Treatment	1	43.027	37.690	0.000*
TOLT	1	35.499	31.095	0.000*
Error	86	1.142		

*Significant at $p < 0.05$.

The analysis showed that students' TOLT scores have significant effect on their post-CCQT scores ($F(1, 86) = 189.528$, $p<0.05$). The results also indicated significant treatment effect ($F(1, 86) = 65.289$, $p < 0.05$). The students in the experimental group who were instructed in pair problem solving technique incorporating with Polya's problem solving strategy demonstrated better performance (adjusted mean = 3.108) on conceptual questions in chemistry over the control group students who were instructed in only Polya's problem solving strategy (adjusted mean = 1.717).

DISCUSSION

The main purpose of this study was to investigate the effects of pair problem solving technique incorporating Polya's problem solving strategy and Polya's problem solving strategy on students' performance on conceptual and algorithmic questions in chemistry. Results revealed that students who were instructed in pair problem solving technique incorporating Polya's problem solving strategy perform better on conceptual and algorithmic questions in chemistry than students who were instructed in Polya's problem solving strategy. This study showed similar results with the studies conducted to examine the effects of think-aloud problem solving technique (Johnson and Chung, 1999; Pate, *et. al.*, 2004). Based on this result, it can be concluded that pair problem solving technique incorporating Polya's problem solving strategy is one of the effective teaching strategies to develop students' conceptual and algorithmic problem solving skills. Pair problem solving technique allowed students to act as active problem solvers and problem checkers.

This process increases students' social interaction. In this approach, students work in pairs and each student works the problem with a partner who does not directly participate in the problem solving but acts as the problem checker and forces the problem solver to verbalize all thought processes. Johnson and Johnson (1986) stated that students who talk through material with peers learn it in a more effective way and retention of information is enhanced in cooperative work because students who work in cooperative relationship are more likely to develop a conscious strategy for how they got to the answer. Tasks which require social interaction will stimulate learning and will enable students to recognize that actions should be taken with reference to others. Polya's problem solving steps and the episodes of pair problem solving technique promote active participation, evidence gathering, interaction between students, discussion, and critical thinking. Thus, according to this study, the combination of pair problem solving technique and Polya's problem solving strategy increases the level of performance of students on conceptual and algorithmic questions in chemistry.

CONCLUSIONS

Most previous studies of problem solving skills have emphasized identification of students' performance of conceptual and algorithmic questions in chemistry. In this study, effects of pair problem solving technique incorporating with Polya's problem solving strategy on undergraduate students' performance of conceptual and algorithmic questions in chemistry were investigated. According to this study, first year university students of the Department of Elementary Education enrolled in general chemistry course improved their performance on conceptual and algorithmic questions using either polya's problem solving strategy or pair problem solving technique incorporating with Polya's problem solving strategy over a seven-week treatment period. It is indicated that a combination of pair problem solving technique and Polya's problem solving strategy is more effective in improving problem solving skills in conceptual and algorithmic questions in chemistry. In addition, students in both experimental and control groups have higher performance in algorithmic questions than in conceptual questions. Further studies should take into consideration that pair problem solving technique based on different problem solving strategies could be employed to investigate students' performance on conceptual and algorithmic question in chemistry.

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APPENDIX

Algorithmic chemistry questions test

1A). 0,100 mole hydrogen gas occupies 10 ml at 127 ^{0}C and 2 atm. If the volume is held constant, which will be the pressure of sample of gas at -23 ^{0}C?

A) 1,25 atm B) 1,5 atm C) 3,25 atm D) 4,08 atm E) 5 atm

2A) Potassium, vanadium, and iron crystallize in a body-centered cubic unit cell. Given the lengths of the unit cell edges (a) and the atomic weight (AW) listed below, which of the elements has the highest density (is the most dense)?

Potassium: a= 5.250 Å, AW= 39.098

Vanadium: a= 3.024 Å AW = 50.942

Iron: a = 2.861 Å AW = 55.847

A) Potassium B) Vanadium C) Iron D) They all have the same density E) Not enough information is given

3 A) For a mixture of 2 mol H_2 and 2 mol O_2 reacting according to the following equation, what is the limiting reagent, and how many moles of the excess reactant would remain after the reaction is completed?

$$2H_2 + O_2 \longrightarrow 2H_2O$$

	Limiting Reagent	Excess Reactant Remaining
a)	O_2	1 mol O_2
b)	O_2	1 mol H_2
c)	H_2	1 mol O_2
d)	H_2	1 mol H_2

e) No reaction occurs since the equation does not balance with 2 mol H_2 and 2 mol O_2.

4A). What is the empirical formula of a compound if a sample of the compounds contains 0,10 mole of P atoms and 1,505 X 10^{23} O atoms?

A) PO_2 B) P_2O_5 C) PO D) P_3O_4 E) P_2O_7

5A) Calculate the maximum weight of NH_3 that could be produced from 1,9 mol of hydrogen and excess nitrogen according to the following reaction.

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

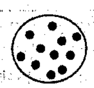
A) 10,76 B) 27,34 C) 21,53 D) 64,60 E) 20,55

6A) Calculate the moles of the following quantities of nitrogen:

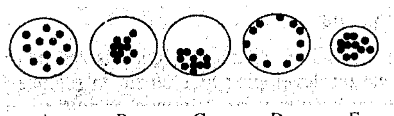
A) 903 molecules B) 1,255X10^{23} atoms

Conceptual chemistry questions test

1B). The following diagram represents a cross-sectional area of a rigid sealed steel tank filled with hydrogen gas at 20^{0}C and 3 atm. pressure. The dots represent the distribution of all the hydrogen molecules in the tank.

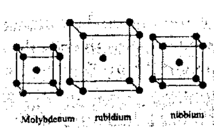


Which of the following diagrams illustrate the most probable distribution of molecules of hydrogen gas in the sealed steel tank if the temperature is lowered to – 5^{0}C? (The boiling point of hydrogen is – 252,8^{0}C).



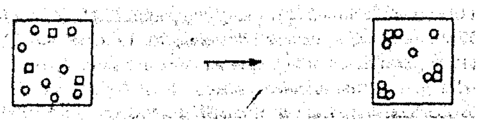
A B C D E

2B). The drawings below are drawn to scale and illustrate the crystal structure of rubidium, niobium, and molybdenum. The atomic weights of these elements are roughly equivalent. Which of the elements has the lowest density (is the least dense)?



A) Niobium B) Rubidium C) Molybdenum D) They all have the same density. E) Not enough information is given

3B). The reaction of element X (□) with element Y (O) is represented in the following diagram. Which of the equations best describes this reaction?



A) $3X + 8Y \longrightarrow X_3Y_8$
B) $3X + 6Y \longrightarrow X_3Y_8$
C) $X + 2Y \longrightarrow XY_2$
D) $3X + 8Y \longrightarrow 3XY_2 + 2Y$
E) $X + 4Y \longrightarrow XY_2$

4B). Two moles of H_2 gas are known to combine with one mole of O_2 gas to form two moles of a substance called water, which we write as H_2O. Which of the following concepts is not associated with understanding this statement?

A) Chemical reactions involve the breaking and rearranging of chemical bonds.
B) Chemical formulas show the ratios of atoms in a molecule.
C) The moles of H_2, O_2 and H_2O are proportionally related to each other.
D) Chemical formulas show the spatial arrangement of atoms in a molecule.
E) The number of moles of water formed are determined by the number of moles of H_2 and O_2.

5B). Any quantity of Cu in excess of one mole will always react with two moles of $AgNO_3$ to produce one mol of $Cu(NO_3)_2$ and two moles of Ag. Therefore we know that 1,5 moles of Cu will react with two moles of $AgNO_3$ to produce 215,74 grams of Ag. Which of the following concepts is the only concept not associated with these statements?

$$Cu + 2AgNO_3 \longrightarrow Cu(NO_3)_2 + 2Ag$$

A) Chemical reactions involve the rearrangement of atoms about one another.
B) In an ordinary chemical reaction mass is not created or destroyed.
C) Identical compounds are always composed of the same elements in the same proportion by mass.
D) Moles of chemical compounds are always conserved in balanced equations.
E) The number of moles of products formed in this case are determined by the number of grams of $AgNO_3$ available.

6B). How many moles of the atoms of B (boron) are present in a sample having $2X10^{23}$ molecules of B_4H_{10}.

Confidence-based assessment in science: an illustrative case study

Evaluación confiable en ciencias: un estudio ilustrativo de caso

CHARLY RYAN

Faculty of Education, University of Winchester, SO22 4NR, UK, Charly.Ryan@winchester.ac.uk

Abstract

Assessment for learning has proven potential for development of learning in science. A study of the use of one approach to assessment for learning, confidence-based assessment, in initial primary teacher education for science shows the potential of this approach for science teacher education in particular, and for science education in general. Furthermore, the study shows how the approach can also be used as assessment as learning, as the assessment activity helps develop the students' learning. The development in confidence that the students felt has implications for other levels of science education. If school students were to be introduced to confidence based assessment it could help increase their confidence in their science knowledge and develop positive companion meanings for science

Key words*: confidence-based assessment, assessment for learning, teacher education*

Resumen

La evaluación para aprender tiene una potencialidad cierta para desarrollar el aprendizaje en ciencias. Éste es un estudio sobre el uso de una manera de hacer evaluación confiable para aprender, dentro de una formación inicial para profesores de escuelas básicas. Muestra las posibilidades de esta estrategia, sea en la formación del profesorado o enseñanza aprendizaje en las escuelas. El aumento de la confianza en los alumnos tiene implicaciones para otros niveles del sistema. Si los alumnos escolares encontraran una evaluación confiable, se podría aumentar su confianza en su aprendizaje en ciencias y desarrollar el significado positivo para su conocimiento científico.

Palabras clave*: evaluación confiable, evaluación para aprender, formación de profesores.*

INTRODUCTION

In the United Kingdom, where this study is set, there has been considerable work done on developing assessment in science. Traditionally, science teachers have been at the forefront of development of assessment of learning, what is it that the learners have learnt as a result of their science programmes (NIEDA, *et al.*, 2004). In the 1990s, there was considerable effort devoted to the concepts of formative and summative assessment and their particular roles in education. Summative assessment was seen as an assessment that established how much a student had learnt. This form of assessment is often used at the end of key stages of education, at transition points from one level to another. So, the results of examinations at the end of secondary school are generally used as an assessment for suitability for work or university. Formative assessment was seen as assessment that was carried out during student learning with a view to supporting that learning. However, detailed analysis of these two forms of assessment showed that the classification depended on the use to which the assessment was put (WILIAM & BLACK 1996). For instance, summative examination scores at the end of primary school could be used for supporting the student's learning in secondary school. What was a summative assessment, end of primary school examination scores, had now become a formative assessment, an assessment used to support the students' learning. In recent years, the emphasis has shifted away from summative and formative assessment, particularly to assessment ***for*** learning (Black et al. 2002) and assessment ***as*** learning (Learning and Teaching Scotland 2005). In assessment ***for*** learning, the role of the assessment is to promote learning and a number of reports have presented the outcomes of a range of assessment strategies that seem to help promote learning (AIAA, 2003; OECD, 2004). In the United Kingdom, teachers in schools are doing much of this research and development work (BLACK, *et al.*, 2003). Assessment as learning is an assessment that allows learners to reflect on their assessment experience. Such reflection develops their metacognitive skills as well as their science learning, and so becomes assessment as learning. Students are learning from the assessment procedure. The work presented here is an account of the use of a new strategy, the use of confidence-based assessment in science teaching. This will show how this strategy can be used as an assessment ***for*** learning as well as an assessment ***as*** learning.

CONTEXT

This study was carried out in a three-year course of initial teacher education. As part of this course, all students have to study modules on how to teach science in the primary school, which are for children from ages 4 to 11. At the time of the study, there were detailed descriptions of what it was that the student teachers should know, both subject content knowledge and pedagogical content knowledge (DfEE, 1998). While these requirements have since been modified (TTA, 2002), most teacher education establishments have carried on using the old criteria for specifying subject content knowledge. The level of this subject knowledge is roughly that of the end of secondary school science examinations. While this study was carried out in initial teacher education, the content level is that applicable to secondary school science teaching. To enter the programme of initial teacher education, all student teachers have to have successfully completed their secondary school science examinations. However to pass the secondary school examination, students do not have to have complete mastery of the material. They need the minimum required to pass. In England, the National Curriculum for science covers the same areas of