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.

ACKNOWLEDGEMENTS

The present study was partially funded by the Secretaría de Extensión Universitaria of the Universidad Nacional de Córdoba. Preliminary results were presented in the XIII Meeting of Physics Education, Rio IV, Argentina, 2003. The authors wish to thank the authorities, teachers and students of the teacher-training institution who participated in this study. They have been supportive of it in many instances and have kindly participated in the activities proposed.

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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

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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 in 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 dos meses después del estudio usando la prueba concepcional (CCQT) y la prueba algorítmica (ACQT). El Test 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, químico, preguntas conceptuales y algorítmicas, resolución en pares, Polya

REVISTA DE EDUCACIÓN EN CIENCIAS
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; BREKEL, et al., 1994; CHEN, et al., 2000; HASS and PARKAY, 1993). The term problem solving is defined by PEZZINO, et al. (1989) as a method of learning as well as an outcome of learning. By GAGNÉ (1977), as a thinking process when the learner recognizes the need to solve a novel problem. RUDD 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. CHU (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), NAKHEL and MITCHELL (1993), MASON, et al. (1997), NIAZ (1995), and CHU (2001) asked students two questions related to the same problem. One question is algorithmic while the other requires algorithmic skills. A second approach is problem solving networks in chemistry. FRAZER and SLEET (1984) and ASAMOAH, et al. (1979) asked students to solve one main problem and its related subproblems. In this approach, students who cannot solve the main problem but who can solve all its component of sub-problems are called algorithmic problem solving; students who can solve the main problem and its related subproblems are called conceptual problem solving. A third approach uses a test which includes M-Demand of different items of content of general chemistry topics. TRAPARLIS, et al. (1998), NIAZ (1988), NIAZ (1987), and NIAZ (1980) 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 algorithmic problem solvers or students 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 (GANS, and BUNGE, 1994). In order 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 (PEZZINO, et al., 1989; HERRON, 1996; GOBEL and BUNGE, 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. Instructing presents facts and equations to be memorized (BODNER, as cited in ZOLLER, 1993; SWIFT, GOODDING 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 theories in 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 MAXMAMOV (2001), one of the studies that emphasized providing a rich environment for students, investigated effects of visual algorithmic-schemata for solving chemistry problems on 10th grade students' performance on "the mass-mol and mol-
lem 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 was 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 female) while the other group formed the control group (n=45; 21 male and 24 female). 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 (Neubrenner and Pickering (1987), Nakilah and Mitchell (1993), Niaz (1995), Sawrey (1990), and Chu (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. What the researchers’ problem solutions were according to Polya’s problem solving strategy, he benefited mostly from Holt Chemistry (2004). In the regular classroom instruction, the instructor taught related concepts through out 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 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 | 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 | 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 | X | SD | Mode | Median | Min-Max |
| CG | 45 | 1.711 | 1.255 | 2.000 | 2.000 | 0-5 |
| EG | 44 | 3.114 | 1.224 | 4.000 | 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 Poly'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 \( r = 0.787, N = 89, p < 0.001 \) 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>
<thead>
<tr>
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<th>df</th>
<th>Mean square</th>
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<th>P</th>
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<tr>
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<td>37.89</td>
<td>65.289</td>
<td>0.000*</td>
</tr>
<tr>
<td>TOLT</td>
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<td>109.98</td>
<td>189.528</td>
<td>0.000*</td>
</tr>
<tr>
<td>Error</td>
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<td>0.580</td>
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</table>

'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 Poly'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 Poly'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>
<thead>
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<th>Sources</th>
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<th>P</th>
</tr>
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<tbody>
<tr>
<td>Treatment</td>
<td>1</td>
<td>43.027</td>
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<td>0.000*</td>
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<tr>
<td>TOLT</td>
<td>1</td>
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<tr>
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</table>

'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 Poly'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 Poly'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 Poly's problem solving strategy and Poly'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 Poly's problem solving strategy performed better on conceptual and algorithmic questions in chemistry than students who were instructed in Poly'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; Park, et. al., 2004). Based on this result, it is concluded that pair problem solving technique incorporating Poly'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. Poly's problem solving steps and the epics of pair problem solving technique promote active evidence gathering, interaction between students, discussion, and critical thinking. Thus, according to this study, the combination of pair problem solving technique and Poly'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 Poly'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 poly's problem solving strategy or pair problem solving technique incorporating with Poly's problem solving strategy over a seven-week treatment period. It is indicated that a combination of pair problem solving technique and Poly'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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Teaching, 19, 511-522.


APPENDIX

Algorithmic chemistry questions test

1A. 0.100 mole hydrogen gas occupies 10 ml at 127 °C and 2 atm. If the volume is held constant, which will be the pressure of sample of gas at -23 °C?

A) 1.25 atm (B) 1.5 atm (C) 1.25 atm (D) 4.08 atm (E) 5 atm

2A. Potassium, vanadium, and iron crystalize 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 H₂ and 2 mol O₂ 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?

2H₂ + O₂ → 2H₂O

<table>
<thead>
<tr>
<th>Limiting Reagent</th>
<th>Excess Reactant Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>O₂</td>
<td>1 mol O₂</td>
</tr>
<tr>
<td>O₂</td>
<td>1 mol H₂</td>
</tr>
<tr>
<td>H₂</td>
<td>1 mol O₂</td>
</tr>
<tr>
<td>H₂</td>
<td>1 mol H₂</td>
</tr>
</tbody>
</table>
| e) No reaction occurs since the equation does not balance with 2 mol H₂ and 2 mol O₂

4A. What is the empirical formula of a compound if a sample of the compound contains 0.10 mole of P atoms and 1.50X 10²⁴ O atoms?

A) PO₂ (B) PO₃ (C) PO (D) PO₄ (E) PO₃²⁻

5A. Calculate the maximum weight of NH₃ that could be produced from 1.9 mol of hydrogen and excess nitrogen according to the following reaction.

N₂ + 3H₂ → 2NH₃

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) 1.25x10²⁴ 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°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°C (The boiling point of hydrogen is ~ 252.8°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 sizes of these elements are roughly equivalent. Which of the elements has the lowest density (is the least dense)?

A) B) C) D)
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 (O) with element Y (O) is represented in the following diagram. Which of the equations best describes this reaction?

A) $5X + 8Y \rightarrow X_5Y_8$
B) $3X + 6Y \rightarrow X_3Y_6$
C) $X + 2Y \rightarrow X_2Y_2$
D) $3X + 8Y \rightarrow 3XY + 2Y$
E) $X + 4Y \rightarrow XY$

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?
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 $2 \times 10^{24}$ molecules of $B_2H_6$.

Confidence-based assessment in science: an illustrative case study
Evaluación confiable en ciencias: un estudio ilustrativo de caso

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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. Este 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 este 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 (NIEDD, 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 (AAIA, 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 (DIEE, 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