# Third Misconceptions Seminar Proceedings (1993)

Paper Title: Changing Student's Conceptions about Non-conservation of Volume in Solutions

Author: Lorenzo-Barral, Francisco M. & Mendoza-Rodriguez, José

Abstract: Pupils' assimilation of certain scientific notions is greatly influenced by their pre-existing ideas. In this study we examined pupils' ideas on the non-conservation of volume during the mixing of liquids. More than two thirds of the subjects retained the misconception that the volume of the mixture is the sum of the volumes of the solute and solvent liquids. However, a conceptual change was performed (and maintained in subsequent years) by students to whom a cognitive conflict strategy was applied using a Predict-Observe-Explain method.

Keywords: Educational Methods,Concept Formation,Testing,Change Strategies,Classroom Techniques,Learning Activities,Cognitive Dissonance,Tests,Pretests Posttests
General School Subject: Chemistry
Specific School Subject: Physical Chemistry
Students: Secondary School

Macintosh File Name: Lorenzo-Barral - Volume
Release Date: 12-16-1993 C, 11-6-1994 I

Publisher: Misconceptions Trust
Publisher Location: Ithaca, NY
Volume Name: The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics
Publication Year: 1993
Conference Date: August 1-4, 1993
Contact Information (correct as of 12-23-2010):
Web: www.mlrg.org
Email: info@mlrg.org

A Correct Reference Format: Author, Paper Title in The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, Misconceptions Trust: Ithaca, NY (1993).

Note Bene: This paper is part of a collection that pioneered the electronic distribution of conference proceedings. Academic livelihood depends upon each person extending integrity beyond self-interest. If you pass this paper on to a colleague, please make sure you pass it on intact. A great deal of effort has been invested in bringing you this proceedings, on the part of the many authors and conference organizers. The

original publication of this proceedings was supported by a grant from the National Science Foundation, and the transformation of this collection into a modern format was supported by the Novak-Golton Fund, which is administered by the Department of Education at Cornell University. If you have found this collection to be of value in your work, consider supporting our ability to support you by purchasing a subscription to the collection or joining the Meaningful Learning Research Group.
----- -----

# CHANGING STUDENT'S CONCEPTIONS ABOUT NON-CONSERVATION OF VOLUME IN SOLUTIONS

Francisco M. Lorenzo-Barral and José Mendoza-Rodriguez
Universidade de Santiago de Compostela, Spain.

Pupils' assimilation of certain scientific notions is greatly influenced by their pre-existing ideas. In this study we examined pupils' ideas on the non-conservation of volume during the mixing of liquids. More than two thirds of the subjects retained the misconception that the volume of the mixture is the sum of the volumes of the solute and solvent liquids. However, a conceptual change was performed (and maintained in subsequent years) by students to whom a cognitive conflict strategy was applied using a Predict-Observe-Explain method.

## INTRODUCTION

It is well known that pupils' assimilation of certain scientific notions is greatly influenced by their pre-existing ideas, which in some cases can seriously obstruct the learning of science. Many authors have stressed that in designing course material on certain topics it is important to take pupils' conceptions into account. Research in this area has aided understanding of the difficulties involved in learning science, and shown the need for changes in science teaching (Gil-Pérez and Carrascosa 1990).

### *Pupils' ideas about solutions*

A number of studies have brought out the variety of alternative conceptions about solutions that are held by pupils of various ages. These studies have concerned the nature of solutions (Cosgrove and Osborne, 1981; Nusirjan and Fensham, 1987; Prieto Ruz, Blanco López and Rodríguez García, 1989a), conservation of mass during the process of dissolution (Andersson, 1984; Fernández, Trigueros and Gordo, 1988) and the microscopic interpretation of dissolution (Holding, 1987; Prieto, Blanco and Rodríguez, 1989b; Longden, Black and Solomon, 1991). Another aspect of dissolution that it is pertinent to consider is the relationship between the volumes of solute, solvent and solution (Figure 1); the non-additivity of the volumes of solute and solvent is not only an important theoretical feature of the dissolution process, but also has practical consequences for the preparation of solutions in the laboratory, this non-additivity being, in part, what makes it necessary for such solutions to be prepared first with a deficit of solvent and then made up to the appropriate volume.

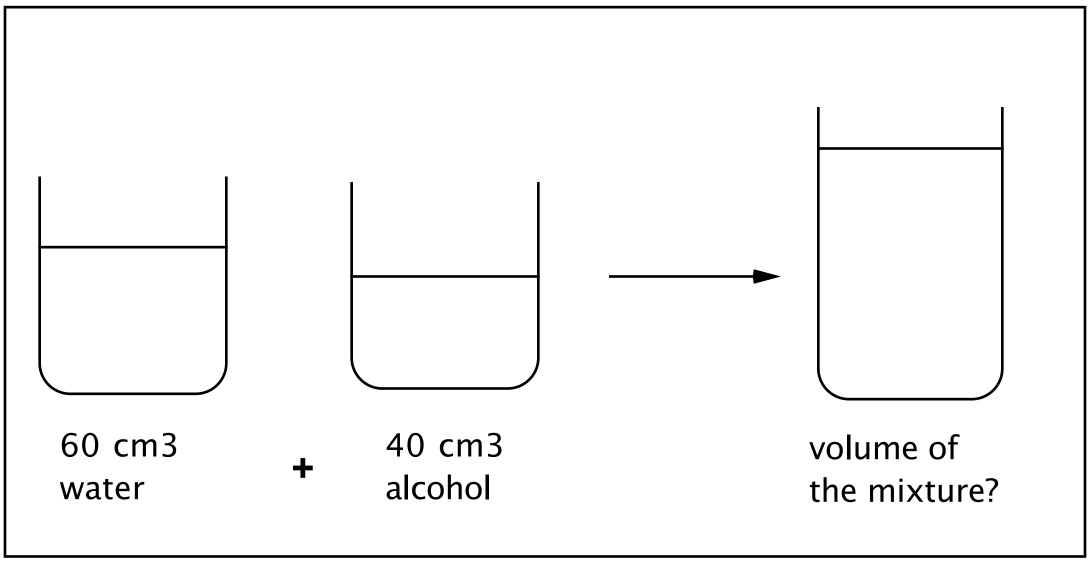


Figure 1.- What is the volume of the mixture?

In this work we studied secondary pupils' notions concerning the conservation of volume during the mixing of two liquids which in fact have a negative excess molar volume (water and ethyl alcohol), and whether misconceptions were successfully corrected by a teaching strategy including cognitive conflict activities.

## METHOD

The study involved three phases: a) a cross-sectional study of the conceptions of pupils belonging to four age groups; b) classroom intervention; and c) a longitudinal post-intervention study.

*a)The cross-agegroup study*

It is important to stress that at no time during the subjects' secondary education did any of their standard textbooks explicitly mention the non-additivity of solute and solvent volumes, though instructions on how to prepare solutions of known molarity implicitly assume awareness of non-additivity. The cross-agegroup study therefore evaluated changes in understanding that had taken place as the result of the pupils' increasing cognitive maturity or the success of unwritten teaching. This study was carried out during the academic year 1991-92 with members of the four agegroups listed in Table 1.

Table1.- Pupils taking part in the cross-agegroup study.

| COURSE | AGE (y) | N. OF PUPILS |
|---|---|---|
| Primary 7 | 12-13 | 25 |
| Middle 2 | 15-16 | 10<br>3 |
| Middle 3 | 16-17 | 50 |
| Upper | 17-18 | 84 |

*b) Classroom intervention*

Classroom intervention specifically designed to make pupils aware of the non-additivity of solute and solvent volumes, and of other aspects of solutions, was carried out in the academic year 1990-91 with a group of 15-16-year-olds. This intervention consisted in activities organized and supervised in the normal classroom situation by the pupils' usual science teacher (one of us, J.M.R.). The activities implemented a Prediction-Observation-Explanation strategy (Champagne, Klopfer and Anderson, 1980) designed to create a cognitive conflict in pupils' minds by bringing out the discrepancy that in most cases existed between their predictions and experimental observations

(Figure 1). Such conflict is equivalent to the dissatisfaction with one's own ideas that Posner *et al*. (1982) postulate as a precondition of conceptual change.

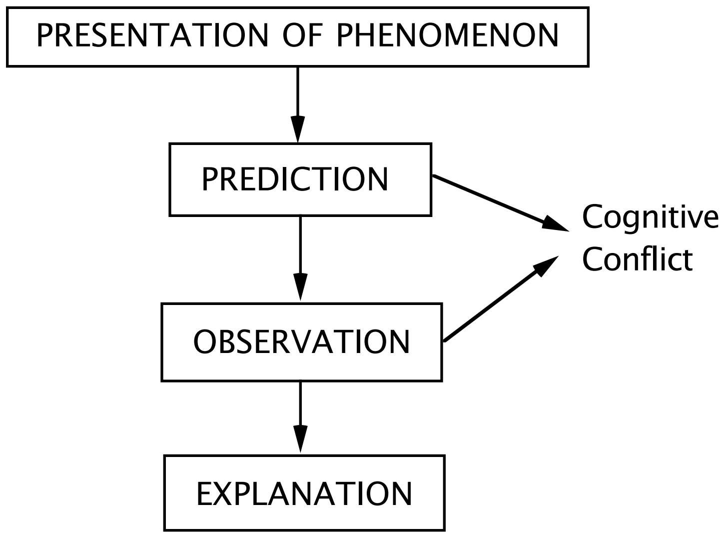


Figure 2.- The order of events during intervention

The specific task the pupils were set (Figure 2) was to predict the volume of a mixture of 60 $cm^3$ of water and 40 $cm^3$ of ethyl alcohol; to perform the experiment and note the volume of the mixture; and to explain in writing why the observed volume was less than 100 $cm^3$.

*c) The longitudinal study*

The pupils subjected to the intervention described above were followed up 10-15 days later and during the following two years to determine changes in their understanding of volumetric non-additivity during the mixing of liquids. The number of pupils examined each year is listed in Table 2; drop-outs were due both to school leavers and to many pupils changing school (several new schools have been built in our community in recent years).

Table 2.- Pupils taking part in the longitudinal study.

| YEAR | COURSE | N.OF PUPILS |
|---|---|---|
| 1990-91 | Middle 2 | 76 |
| 1991-92 | Middle 3 | 42 |
| 1992-93 | Upper | 24 |

*Data collection*

The pupils' predictions of the volume of the mixture were solicited with the following multiple choice question, one of six on a broader test paper administered after completion of a learning unit on solutions:

*When 40 $cm^3$ of alcohol are mixed with 60 $cm^3$ of water, what is the volume of the mixture?*

*A. More than 100 $cm^3$*
*B. 100 $cm^3$*
*C. Less than 100 $cm^3$*
*D. Don't know*

The four choices thus comprised the correct answer, a "don't know" option to minimize random replies, and two distractors.

During the intervention phase, pupils' explanations of their observations were collected in writing.

## RESULTS, ANALYSIS AND DISCUSSION

*a) The cross-agegroup study*

Table 3 lists the percentage of each agegroup choosing each possible answer to the multiple choice question.

Table 3.- Percentage of each agegroup giving each possible answer to a multiple choice question on conservation of volume during the mixing of two liquids.

| Answer | 12-13 y | 15-16 y | 16-17 y | 17-18 y |
|---|---|---|---|---|
| More than 10( | 4 | 3 | 4 | 2 |
| 100 $cm^3$ | 60 | 78 | 64 | 68 |
| Less than 100 | 24 | 18 | 32 | 26 |
| Don't know | 12 | 1 | 0 | 4 |

Most replies show that pupils retained a misconceived idea of the additivity of the volumes of the components of a mixture. About two-thirds of the pupils predicted strict additivity, and this proportion was unaltered by five years' standard teaching. We believe that, as with other misconceptions, this one has its origin largely in the persuasiveness of appearances (Driver, 1989). Pupils believe that volumes are additive because they see the mixing operation as analogous to the addition of two volumes of water (which *is* additive, of course). Thus the origin of this incorrect belief in the additivity of volumes is similar to that of the incorrect belief in the nonadditivity of mass during solution (Stavy, 1990), (pupils tend to believe that sugar or salt dissolved in water contribute nothing to the weight of the solution - or contribute less than their undissolved weight - because they are seen to disappear upon solution).

*b) Intervention*

The experimental group's explanations of their experimental observation (that the mixture of alcohol and water occupied a smaller volume than the separate components) were classified in seven categories (Table 4). Most pupils resorted to macroscopic explanations, most of which simply restated the experimental observation or some aspect of the experimental situation ("upon dissolving", "because it contracts"). Only 16% of the pupils attempted a microscopic interpretation in terms of the behaviour of the particles constituting the mixture.

Table 4.- Percentage of pupils offering various kinds of explanation for the observed volumetric nonadditivity of alcohol and water.

| Category | Percentage |
|---|---|
| 1. The particles move or join together | 16 |
| 2. The liquids have different densities | 20 |
| 3. Because of evaporation | 7 |
| 4. Because of losses on mixing | 13 |
| 5. Upon dissolving | 12 |
| 6. Because it contracts | 12 |
| 7. No answer | 20 |

*c) The longitudinal study*

Table 5 lists the results of the experimental group at each follow-up time. Most of these pupils successfully assimilated the volumetric nonadditivity of liquid mixtures, and retained this knowledge during subsequent years. Thus the persistence of the belief in additivity that emerged in the cross-agegroup study was not due to the intrinsic intractability of this notion, but simply to this aspect of mixtures having been ignored in standard textbooks.

Table 5.- Percentage of pupils giving each possible answer to a multiple choice question on conservation of volume during the mixing of two liquids, after doing the experiment and during follow-up.

| Answer | 1990-91 | 1991-92 | 1992-93 |
|---|---|---|---|
| More than 100 cn | 6 | 0 | 4 |
| 100 $cm^3$ | 24 | 33 | 29 |
| Less than 100 cm | 70 | 67 | 67 |
| Don't know | 0 | 0 | 0 |

*Discussion*

The chief lesson to be learned from this work is that the assimilation of certain scientific topics is facilitated if teachers and syllabus designers are aware of pupils' difficulties and include, in their classroom teaching or syllabuses, activities specifically aimed at overcoming these difficulties. In the case of the topic on which this work centred, our results clearly imply that volumetric nonadditivity should be explicitly dealt with during class activities on solutions. Since the predominant misconception (additivity) seems to have a largely perceptual origin (the volume of the mixture appears to be the sum of the volumes of the original components), it would be desirable for such activities to involve mixtures that are rather spectacularly nonadditive, such as sulphuric acid and water (though in this particular case the activity would for safety reasons have to be a demonstration by the teacher). Only in this way does it seem likely that certain scientific topics will be successfully learnt by a substantial percentage of pupils.

**Acknowledgement**

This work was supported by the Xunta de Galicia under grant XUGA 22701B91.

**REFERENCES**

Andersson, B. (1984). Chemical Reactions. *EKNA Project*. University of Goteborg: Sweden.

Champagne, A.B., Klopfer, L.E. and Anderson, J.H. (1980). Factors influencing the learning of classical mechanics. *American Journal of Physics*, **48**, 1074-1079.

Cosgrove, M. and Osborne, R. (1981). Physical Change. Working Paper Nº 26. *Learning in Science Project*. University of Waikato: Hamilton, N.Z.

Driver, R. (1989). Más allá de las apariencias: la conservación de la materia en las transformaciones físicas y químicas. In R. Driver, E. Guesne and A. Tiberghien (Eds) (pp. 223-258). *Ideas Científicas en la infancia y adolescencia*. MEC-Morata: Madrid, .

Fernández, J.M., Trigueros, T. and Gordo, L. (1988). Ideas sobre los cambios de estado de agregación y las disoluciones en alumnos del 2º curso del BUP. *Enseñanza de las Ciencias*, **6** (1), 42-46.

Gil-Pérez, D. and Carrascosa, J. (1990). What to Do About Science "Misconceptions". *Science Education*, **74** (5), 531-540.

Holding, B. (1985). Aspects of secondary students' understanding of elementary ideas in Chemistry: summary report. *Children's Learning in Science Project*. University of Leeds: Leeds, U.K.

Longden, K., Black, P. and Solomon, J. (1991). Children's interpretation of dissolving. *International Journal of Science Education*, **13** (1), 59-68.

Nusirjam and Fensham, P. (1987). Descriptions and frameworks of solutions and reactions in solutions. *Research in Science Education*, **17**, 139-148.

Posner, G.J., Strike, K.A., Hewson, P.W. and Gertzog, W.A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, **66**, 211-227.

Prieto Ruz, T., Blanco López, A. and Rodríguez García, A. (1989a). Explicaciones de los alumnos de 2a etapa de E.G.B. sobre el concepto de reversibilidad del proceso de disolución. *Investigación en la Escuela*, (7), 79-90.

Prieto, T., Blanco, A. and Rodríguez, A. (1989b). The ideas of 11 to 14-year-old students about the nature of solutions. *International Journal of Science Education*, **11** (4), 451-463.

Stavy, R. (1990). Pupils' problems in understanding conservation of matter. *International Journal of Science Education*, **12** (5), 501-512.