DOCUMENT RESUME

ED 368 581 SE 054 353

AUTHOR	Odom, A. Louis; Settlage, John
TITLE	High School Students' Understandings of Diffusion Concepts in Relation to Their Levels of Cognitive Development.
PUB DATE	Mar 94
NOTE	7p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (Anaheim, CA, March 19-24, 1994).
PUB TYPE	Reports - Research/Technical (143) -- Guides - Non-Classroom Use (055)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	Biological Sciences; *Cognitive Development; Constructivism (Learning); *Diffusion (Physics); High Schools; Physical Sciences; *Science Instruction; Scientific Concepts
IDENTIFIERS	*Conceptual Change

ABSTRACT

The concept of diffusion may seem easy enough for many teachers to understand, but when and what do students really understand about diffusion and osmosis? In order to answer these two questions, 116 students (46.6% in the tenth grade, 30.2% in the eleventh grade, and 23.2% in the twelfth grade) enrolled in biology classes were administered tests to assess for their level of cognitive development and their understandings of diffusion and osmosis. Results revealed that while there were significant differences in level of cognitive development, significant differences between grade levels and gender did not exist. The researchers asked teachers to not assume that a concept can be easily understood by students simply because it is basic knowledge. Instead they should be aware of the fact that students must have a working knowledge of other concepts before they can truly understand more abstract concepts. (ZWH)

HIGH SCHOOL STUDENTS' UNDERSTANDINGS OF DIFFUSION CONCEPTS IN RELATION TO THEIR LEVELS OF COGNITIVE DEVELOPMENT

A. LOUIS ODOM, UNIVERSITY OF MISSOURI-KANSAS CITY
JOHN SETTLAGE, JR., CLEVELAND STATE UNIVERSITY

Paper presented at the annual meeting of the National Association of Research in Science Teaching,
Annaheim, California
March 26-29, 1994

High School Students' Understandings of Diffusion Concepts in Relation to their Levels of Cognitive Development

A. Louis Odom, University of Missouri--Kansas City
John Settlage, Jr., Cleveland State University

Paper presented at the annual meeting of the National Association of Research in Science Teaching, Anaheim, CA, March 26-29, 1994.

Introduction

The purpose of this study was to investigate the possible relationships between an individual's level of cognitive development and their understanding of diffusion and osmosis. The concept of diffusion is very common in science instruction, and understanding the concept is an important precursor to instruction in life science (e.g., many physiological functions) and physical science (e.g., rates of reaction). Because of the abstract nature of the concepts of diffusion and osmosis, it was appropriate to investigate 1) what aspects of these concepts were understood by high school students and 2) how the understandings of the concepts related to the students' Piagetian levels of cognitive development. Findings of this study have implications for methods of instruction about diffusion and osmosis.

Significance

The understanding of abstract concepts has been shown to be predicated by an individual reaching a formal reasoning as measured with Piagetian tasks (Lawson & Renner, 1975). The concepts of diffusion and osmosis can be easily found in many science curricular materials; a cursory examination of widely-used high school biology textbooks revealed that these concepts are addressed by every publisher. It would appear that curriculum writers regard these concepts as important buildings blocks to the understanding of bigger scientific ideas. If the concepts are as abstract as some claim (e.g., Simpson and Marek, 1988), then what is the likelihood that a teacher can successfully teach the concepts when the students have not attained the ability to engage in formal reasoning? This study sought to contribute to the body of research about students' understandings of science concepts.

Design and Procedures

Students enrolled in Biology I and Biology II at a suburban public high school served as the subjects for this study. The school was located in a large, midwestern metropolitan area. A total of 116 students (twice as many females as males) were assessed for their level of cognitive development and their understandings of diffusion and osmosis. Of the students in this study, 46.6% were in the tenth grade, 30.2% were in the eleventh grade, and the remaining 23.2% were in the twelfth grade.

Understandings of diffusion and osmosis were assessed using the Diffusion and Osmosis Diagnostic Test (DODT) developed by Odom (1992). The DODT is a two-tiered test, a genre of assessment tools that objectively evaluates the reasons behind individuals' ideas. As with other two-tiered tests (Treagust, 1985) each item on the DODT consists of a first tier that is a multiple choice response content question and second tier that requires the individual to choose a reason that matches their content response. A survey sheet appended to the DODT asked for students to indicate their grade level and gender. The DODT has a split-half reliability of 0.71 among this age of students.

Each student's level of cognitive development was determined through the administration of the Logical Reasoning Test (Popejoy & Burney, 1990). This multiple choice test uses situations akin to Piaget's interview tasks and has a calculated reliability of .704 using KR-20 . Student scores on the test was used to classify each student as a concrete, transitional, or formal reasoner.

A 3 × 2 factorial ANCOVA statistical analysis was used in this study with grade level as the covariate, and gender and level of cognitive development as independent variables. All statistical analyses were conducted with the program SYSTAT 5.03 (SYSTAT, 1992).

Findings

A test of the main effects using analysis of covariance revealed statistically significant differences for level of cognitive development. Grade level and gender were not significantly different ($p > .05$). A post hoc Tukey test showed no statistically significant difference between concrete and transitional reasoners' understandings of diffusion and osmosis, but there were statistically significant differences between formal reasoners and the other groups ($p < .05$). For the remainder of this study, the distinction between concrete and transitional reasoners was removed; these two groups were collapsed together and were called preformal reasoners and their responses on the DODT were contrasted with those of the formal reasoners.

The DODT was designed to evaluate understanding of several concepts related to diffusion and osmosis. These concepts are listed in Table 1 along with the items from the DODT that specifically assess each concept.

Table 1. Percent of correct response by concept on the Diffusion and Osmosis Diagnostic Test by level of cognitive development.

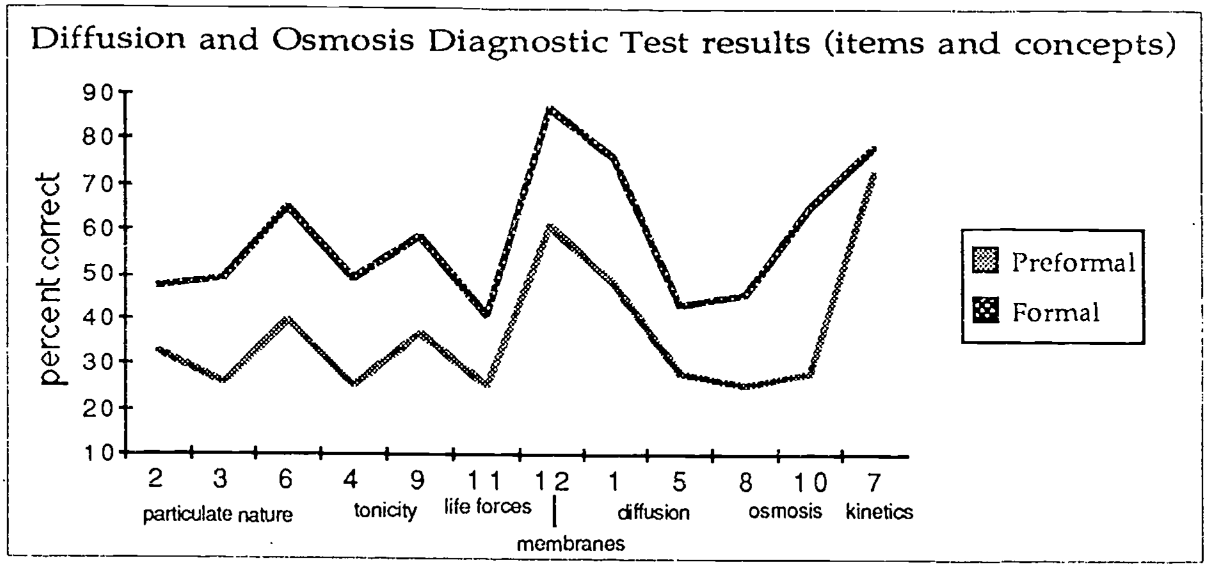
Concept	Test item(s)	Composite	Preformal	Formal
Particulate and Random Nature of Matter	2	38.8	32.9	47.8
	3	35.8	26.4	50.0 **
	6	50.0	40.0	65.2 **
Concentration and Tonicity	4	35.3	25.7	50.0 **
	9	45.7	37.2	58.7 *
Influence of Life Processes on Diffusion and Osmosis	11	31.9	25.7	41.3
Membranes	12	71.6	61.5	87.0 **
Process of Diffusion	1	59.5	48.6	76.1 **
	5	43.5	28.5	43.5
Process of Osmosis	8	33.6	25.7	45.7 *
	10	43.1	28.5	65.2 **
Kinetic Energy of Matter	7	75.0	72.8	78.3

* $p < .05$, ** $p < .01$ when Preformal was compared to Formal

Statistically significant differences were found to exist for items Three and Six (Particulate and Random Nature of Matter), items Four and Nine (Concentration and Tonicity), item Twelve (Membranes), item One (Process of Diffusion), and items Eight and Ten (Process of Osmosis). Differences in the number of correct responses were not statistically significant for Items Two, Five, Seven, and Eleven. From the composite scores it can be seen in Table 1 that the concepts about which the greatest percentage of subjects in this study selected the desired responses were the kinetic theory of matter followed by their understanding of diffusion across a semi-permeable membrane. The concept that the fewest number of students understood was the influence of life processes on diffusion and osmosis.

A graphical representation of preformal versus formal reasoners' responses on the DODT items is presented here as Figure 1. This graph shows that formal reasoners outperformed preformal reasoners on every DODT item.

Figure 1. Comparison of preformal versus formal reasoners responses by item on the DODT. (N = 116)



Discussion

A prior study that used the DODT revealed similar response patterns with college students (Odom & Barrow, 1993). Just as with the high school students in the current study, college students had difficulty in selecting the desired content response and associated reason for Item Two. The speculation is that for many students, the stumbling block was the terminology in the reason provided: students in both studies may have confused the term "isotonic" to mean that the particles were evenly distributed rather than the more scientific definition of equivalent water concentrations across a membrane. Overall, there were no dramatic variations in the types of conceptions and reasons indicated by college versus secondary science students.

In order to understand diffusion and osmosis, students must have a working knowledge of concepts such as solute, concentration, solubility, and dilution (Johnstone & Mahmond, 1980). To suggest that diffusion and osmosis are simple concepts because they are so basic is inaccurate. A teachers' perception of the simplicity of diffusion fails to take into account the abundance of events that underlie the process. Giving a "brief" overview of diffusion and osmosis before discussing plant turgor pressure or the action of a kidney nephron is a disservice to students who, in spite of their best efforts, are not being given the necessary cognitive tools to process all of the information presented to them.

This study's results may help a science teacher address the question: "What can I do to increase the likelihood that my students will understanding diffusion and osmosis?" A study of the changes in high school students' conceptions of natural selection led to the proposal of a landscape metaphor that could describe the most likely routes by which students ideas might change (Settlage, 1994). In terms of understanding natural selection, high school students' explanations readily shifted from the idea of organismal need toward explanations that invoked species variation as an important factor. However, few students seemed capable of making the conceptual shift that included random generic mutations to explain natural selection.

It seems probable that a similar conceptual landscape may emerge for diffusion and osmosis concepts. Kinetic energy of matter and the movement of molecules across semipermeable are ideas that come more easily to most students than does the concept of the influence of life processes upon diffusion and osmosis. The implication is that there may exist a certain sequence in which the concepts ought to be addressed in order to maximize the potential for student understanding. In fact, Simpson and Marek (1988) identified key ideas necessary for students to know prior to their ability to construct a scientifically appropriate understanding of diffusion.

It is somehow ironic that in an earlier analysis of secondary students' conceptual understandings of abstract concepts and the relationship to cognitive development, Lawson and Renner (1975) were critical of the "new" science curricular projects of the 1960s in that the content being prescribed was apparently beyond the reasoning capabilities of the target students. As the science education community finds itself in the midst of another reform movement, we can't help but wonder if we have learned from the mistakes of our predecessors or if we are treading a path that once again will fail to lead us to our desired goal.

We agree with the assertions put forth by Westbrook and Marek (1992) for enhancing science instruction. They investigated students' conceptions of homeostasis, another fundamental science concept, and used their findings to support their argument for the application of a learning cycle approach (Renner & Marek, 1988) that takes advantage of the social interactions built into this pedagogical model. Perpetuating the use of the learning cycle throughout science instruction for pre-college populations seems to be an important step toward increasing students learning of key science concepts such as diffusion and osmosis.

References

Johnstone, A. H. & Mahmond, N. A. (1980). Pupils problems with water potential. Journal of Biological Education, 14, 325-328.

Lawson, A. E. & Renner, J. W. (1975). Relationships of science subject matter and developmental levels of learners. *Journal of Research in Science Teaching*, *12*, 347-358.

Odom, A. L. & Barrow, L. H. (1993, April) *Freshman biology majors misconceptions about diffusion and osmosis*. Paper presented at the annual meeting of the National Association of Research in Science Teaching, Atlanta, GA.

Odom, A. L. (1992). The development and validation of a two-tier diagnostic test measuring college biology students' understanding of diffusion and osmosis. Unpublished doctoral dissertation, University of Missouri--Columbia.

Popejoy, W. D. & Burney, G. M. (1990). The construction and validation of an objective formal reasoning instrument. In M. B. Rowe (Ed.), *What research says to the science teacher: The process of knowing* (pp. 99-115). Washington, DC: NSTA.

Renner, J. W. & Marek, E. A. (1988). *The learning cycle: Elementary school science teaching*. Portsmouth, NH: Heinemann.

Settlage, J. H. (1994). Conceptions of natural selection: A snapshot of the sense-making process.Journal of Research in Science Teaching, 31 (5).

Simpson, W. D. & Marek, E. A. (1988). Understandings and misconceptions of biology concepts held by students attending small high schools and students attending large high schools. *Journal of Research in Science Teaching*, *25*, 361-374.

SYSTAT. (1992). *SYSTAT: Statistics*, version 5.03. Evanston, IL: SYSTAT.

Treagust, D. F. (1985, April). *Diagnostic test to evaluate students' misconceptions in science*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, French Lick Springs, IN.

Westbrook, S. L. & Marek, E. A. (1992). A cross-age study of student understanding of the concept of homeostasis. *Journal of Research in Science Teaching*, *29*, 51-61.