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ABSTRACT

Expert/novice studies of conceptually rich problem solving have demonstrated a relationship between the correctness of a solution and the extent and organization of the solver's conceptual knowledge. This study examines meaningful problem solving and the relationship between the correctness of a solution and the extent of the solver's scientific conceptual knowledge. Fourteen high school students participated in this qualitative study involving a problem in osmosis. The investigative course consisted of a presolving clinical interview, a think-aloud solving of the problem, and a retrospective report of the solving course. Results indicate that 13 of the 14 solving courses were meaningful. Four of the 13 meaningful solutions were correct. However, two of these four correct solutions were embedded in nonscientific conceptual knowledge about air pressure. (Contains 13 references.) (PR)

A BREACH IN THE RELATIONSHIP BETWEEN CORRECTNESS AND SCIENTIFIC CONCEPTUAL KNOWLEDGE FOR THE MEANINGFUL SOLVING OF A PROBLEM ABOUT OSMOSIS

by

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Introduction

Expert/novice studies of conceptually rich problem solving have demonstrated a relationship between the correctness of a solution and the extent and organization of the solver's conceptual knowledge (Chi, Glaser, & Rees, 1981). The report undertaken here is about meaningful problem solving and the relationship between the correctness of a solution and the extent of the solver's scientific conceptual knowledge. Meaningful problem solving refers here to problem solving that is guided by conceptual knowledge (Stewart, 1982). The term scientific conceptual knowledge refers here to personal conceptual knowledge that is appropriate to the problem and compatible with public science knowledge. The major finding of this study was to identify a direct relationship between the correctness of a solution and the scientific conceptual knowledge associated with the meaningful solving of a graphing problem about osmosis.

The results of this study, however, also showed that meaningful solving courses can generate correct solutions from nonscientific conceptual knowledge, that is, from conceptual knowledge that is incompatible with appropriate public science knowledge. In this qualitative study, solvers meaningfully solved a graphing problem about osmosis. Furthermore, several solvers generated a solution that conformed in every respect to the model graph. Yet some who generated correct solutions had misconstrued the problem as being about air pressure. Thus the relationship between the correctness of their solutions and the scientific conceptual knowledge of their solving courses was breached. The purpose of this report is to identify a condition of meaningful problem solving associated with this breach in the relationship between correctness and scientific conceptual knowledge.

Meaningful problem solving has been valued as a desired outcome of science instruction (Stewart, 1983). It is often assumed that meaningfully-generated correct solutions must have been derived from essentially scientific conceptual knowledge. For example, teachers, in assessing students, assume that correct solutions signify scientific conceptual knowledge. This report is important for identifying a condition associated with a breach in this relationship. Obviating this condition would help teachers to secure inferences of scientific conceptual knowledge based on the correctness of a solution, as long as the solving course was meaningful.

Method

The solvers for this study were 14 high school students. In an attempt to constrain meaningful solving courses, the solvers were novices with respect to the problem. The term novices refers in this study to solvers who, irrespective of their conceptual knowledge, are solving a problem that heretofore has been unfamiliar. This study specified that the solvers be novices with respect to the problem in order to obviate prescribed algorithms. The use of prescribed algorithms has been associated with meaningless solving courses, solving courses independent of conceptual knowledge (Gabel, Sherwood, & Enochs, 1984; Lythcott, 1990; Stewart, 1983; Yarroch, 1985). Thus, in an attempt to secure the meaningfulness of the solving courses, this study specified that the solvers be novices with respect to the problem.

The problem was embedded in the conceptually rich domain of osmosis. A problem about osmosis was selected firstly because osmosis is a difficult topic (Friedler, Amir, & Tamir, 1985, 1987; Johnstone & Mahmoud, 1980a). Personal notions of osmosis commonly abound with nonscientific conceptions (Friedler et al., 1985, 1987; Johnstone & Mahmoud, 1980b; Murray, 1983; Okeke & Wood-Robinson, 1980). Secondly, students are likely to have encountered the topic in high school biology. Yet they are unlikely to be familiar with specific problems about osmosis because biology teachers do not tend to use problem solving as an instructional strategy except during lessons in genetics. (See Figure 1, Statement of the problem under study.)

Most students, however, are unable to solve an unfamiliar science problem (Eylon & Linn, 1988). To enhance the likelihood for the solving of an unfamiliar problem about osmosis, the novices for this study were selected from students who had completed at least two years of high school science, including at least one year of biology, and who had been designated by their teachers as efficient science learners. The term efficient science learners refers here to those students who, relative to their peers, have had considerable experience solving science problems in general and have extensive conceptual knowledge. Thus, to both constrain and ensure meaningful solving courses, the solvers for this study were novices with respect to the problem and efficient science learners.

The investigative course consisted of a presolving clinical interview, a think-aloud solving of the problem, and a retrospective report of the solving course. Before being given the problem statement, each subject was clinically interviewed about osmosis and graphing to identify elements of conceptual knowledge that could be embedded in the solving course. Then the problem was presented, and each solver generated a

A Problem about Osmosis

The figure below is a diagram of an inverted thistle top funnel which can be used to demonstrate osmosis. At the beginning of an experiment there is a dilute solution of sugar and water inside the funnel. An inelastic membrane permeable only to water has been fitted across the immersed funnel opening. The funnel is surrounded by pure water.

Make a graph to show how the solution level in the stem of the funnel changes with time.

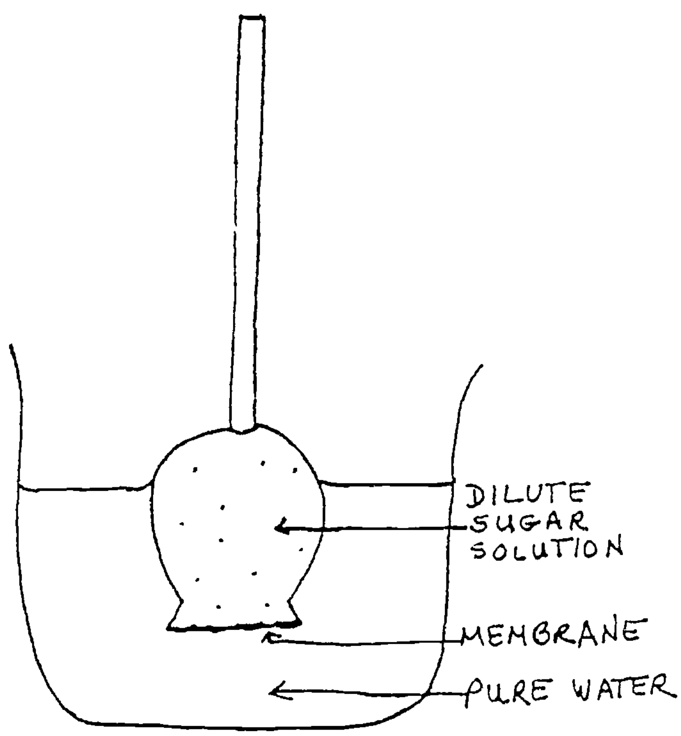

Figure 1. Statement of the problem under study.

think-aloud protocol, pencil-and-paper solution, and retrospective report of the solving course.

Each investigative course yielded assessments for the a) meaningfulness of the solving course, b) correctness of the solution, c) scientific conceptual knowledge context of the solving course, and d) novice status of the solver. A solving course was judged to be meaningful firstly if the think-aloud protocol and retrospective report consisted of a series of inferences that moved the solver toward the solution and secondly if the inferences were justifiable by conceptual knowledge.

The pencil-and-paper solution was assessed as correct if it conformed with attributes of the model graph. (See Figure 2, The model solution.) Additionally, the solver's think-aloud protocol and retrospective report must have supported the conventional meaning of the graph, that is, the solution's rising at a uniformly diminishing rate until the equilibrium point.

The conceptual knowledge context of the solving course was judged to be scientific if data from the clinical interview, think-aloud protocol, and retrospective report indicated that the solving course was embedded in an essentially accurate osmotic representation. For an essentially accurate osmotic

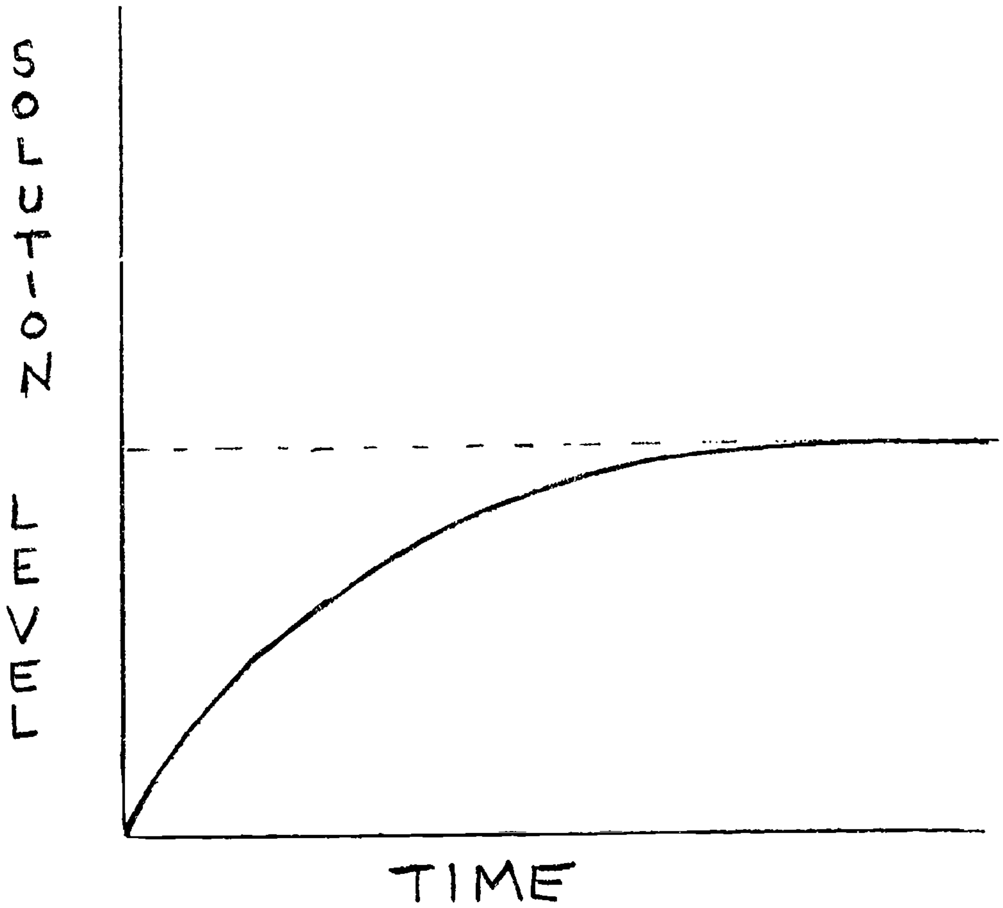

Figure 2. The model solution:

Solution level as a function of time.

representation, the significance of either the concentration difference or membrane permeability must have been explicitl stated, and its effects, correctly interpreted.

Finally, the solver was judged to be a novice with respect to the problem if, when asked during the retrospective report, the solver reported having no recollection of having previously tried to solve that problem or an isomorph. The data from subjects reporting such a recollection were excluded from the study.

In summary, this report is a qualitative study of efficient science learners who were novices with respect to a graphing problem about osmosis. Each investigative course consisted of a presolving clinical interview, a think-aloud solving of the problem, and a retrospective report of the solving course. For each novice, the meaningfulness of the solving course, its scientific conceptual knowledge context, and the correctness of the solution were assessed.

Results

Thirteen of the 14 solving courses were meaningful. Four of the 13 meaningful solving courses generated correct solutions. Yet two of these four meaningfully-generated correct solutions were embedded in nonscientific conceptual knowledge about air pressure. Both solvers attributed the movement of water into the funnel to a greater air pressure over the beaker as compared with over the stem of the funnel. Despite the fact that their graphs conformed in every respect with the model solution, the notion of osmosis never entered into their interviews or protocols.

Conclusion

This is a report of a breach in the relationship between the correctness of solvers' meaningfully-generated solutions and their scientific conceptual knowledge. Correct solutions to a graphing problem about osmosis were meaningfully generated in the context of nonscientific conceptual knowledge about air pressure. This breach was attributed to the fact that the correct solution is a graph with a standard curve. More than one problem representation could meaningfully generate the same graph.

Thus the correct solution to a meaningfully-solved problem can be embedded in nonscientific conceptual knowledge. Correct solutions to even meaningfully-solved problems can obscure the conceptual deficiencies of a solver. For the meaningful solving of a problem that involves graphing, it behooves those who assume that a correct solution indicates the solver's scientific conceptual knowledge to secure the relationship between correctness and scientific conceptual knowledge with problems having correct solutions that are distinctive rather than standard.

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