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ABSTRACT

A study examined the role of prior knowledge in teacher-generated analogies and student-generated analogies that convey the concept of protein synthesis. Subjects were 269 eighth-grade students enrolled in a public school district in a northern suburb of Chicago, Illinois. Subjects were divided into groups that received traditional instruction, generated their own analogies, or received teacher-generated analogies for instruction. Student performance was measured using a publisher's multiple-choice test and a short-answer test to assess knowledge about protein synthesis before instruction, immediately after instruction, and one month after instruction. Results indicated that in both the immediate posttest and the one-month posttest, prior knowledge was a significant variable in predicting the student's performance on the posttests. Findings suggest that a foundation of science knowledge seems requisite to the efficient and effective use of teacher-generated analogies as well as student-generated analogies. Teachers should take pains to use analogies based on domains already familiar to the students and should make clear the semantic and structural correspondences between the analogs that are important for providing the desired explanation. (Contains 16 references and 2 tables of data.) (RS)

The Role of Prior Knowledge in Analogy Use

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Analogy use as an instructional tool for teachers has had some proven success. Analogies are a technique to link the old knowledge to the new knowledge. Their use has been found to force the learner to reexamine old knowledge to meet the demands of the new knowledge (Duit, 1991). Analogies can also facilitate an understanding of the abstract of many science concepts by pointing to similarities between prior knowledge of the learner.

Students frequently use analogical reasoning when solving problems. Because students (in grammar school, high school, or college) are novices most of the time in most subject areas, referring to their own experience or to solutions produced by other examples is a valuable alternative to solving problems. Analogical problem solving; however, is often used by experts, especially in situations where the problem is difficult, even for them (Chi, 1981). Experts will then attempt to reason from a domain they understand well, to the one that is puzzling. This kind of knowledge-rich analogical reasoning is hardly observed in novices (Chi, Feltovich & Glaser, 1981). What novices often do; however, is employ a type of analogical reasoning where they use worked-out examples provided in textbooks, by the teacher, or by their peers when solving new problems (Smith, Good & Roschelle, 1992).

Recent interest in the use of analogies in science education has centered around several aspects of analogy including teachers' analogical explanations in the classroom. Despite almost a decade of research generated from this interest in analogies in science education, few studies have investigated or described the effectiveness of analogies in the classroom and the role of prior knowledge, and those have been teacher-generated analogies. The role of prior knowledge in analogy use was the focus of this study. The purpose of this study is to examine the role of prior knowledge in teacher-generated analogies and student-generated analogies.

Alexander and Kulikowich (1991) examined the role of domain knowledge, analogic reasoning ability, and interactive knowledge played in the comprehension of scientific exposition. They found that students need some degree of biology knowledge before the teacher-generated analogies were effective. Zook & Maier (1994) also demonstrated that eighth grade biology students' ability to process an analogy and respond to factual information was related to verbal ability, gender and was context-specific. They found that females with high verbal skills processed the science analogies more effectively.

This past research has been generated from the perspective of the teacher and not that of the student. Even if the teacher tries to use analogies to situations that are familiar to the students, failures can arise because the students' knowledge is not in fact organized the way the teacher thinks it is. Good teaching requires knowing what the students think and how they think. This study extended previous work by focusing on the effects of teacher versus students analogy in learning science concepts. The research questions were:

1. Are teacher and student-generated analogies more effective than traditional instruction in bringing about change in students' understanding of a given scientific concept?
2. What is the nature of the change?
    a. How are student-generated and teacher-generated analogies related to the student's subject-matter knowledge?

Methodology

This study investigated the differences between the use of teacher-generated analogies, student-generated analogies and traditional instruction (lecture and discussion) to convey the concept of protein synthesis, a difficult and abstract concept for junior high students to understand. There were 269 eighth grade science students in a suburban city of Chicago.

Participants

The participants in this study were 269 eighth grade students enrolled in a public school district in a northern suburb of Chicago, Illinois. The researcher used her class of 135 students and another cooperating teacher's class of 134 students.

Procedure

The participants were divided into a total of six groups. Three groups were organized within the cooperating teacher's class and three groups within the researcher's class. These three groups consisted of a) control group from both the researcher's class (n=44) and the cooperating teacher's class (n=44) that received traditional instruction (total n=88), b) a group of students from both the researcher's class (n=44) and the cooperating teacher's class (n=44) that generated their own analogies as an instructional method and, c) a group from both the researcher's class (n=41) and the cooperating teacher's class (n=41) that received a teacher-generated analogy for instruction (n=82). All research was conducted during the spring and the material and tests used for this research was integrated into the regular curriculum for the students.

The instructional intervention of protein synthesis lasted one week. All of the groups received four days of traditional instruction on the topic of protein synthesis. The first day consisted of a review of cell organelles. The ten sequential steps of protein synthesis were then superimposed on the drawing as the process was explained. In addition, all students received a two page handout that contained the basics of protein synthesis.

On the second day, all six groups completed an activity that required the students to review and sequence the steps of protein synthesis. At the end of class, all students were given an illustration of protein synthesis to be taken home and colored for homework.

On the third day, the students received different instruction depending on the group to which they assigned. The two control groups engaged in additional practice by completing an activity that required them to "decipher" a triplet code message. The students in the teacher-generated group discussed a textbook/teacher analogy for protein synthesis, and the student-generated groups were given instructions to create their own analogy of protein synthesis. They were instructed to map an entire "system", meaning that all of the parts of their analogy had to relate to a singular topic.

On the fourth day all students reviewed protein synthesis through a teacher discussion; however, the student-generated groups shared their analogies with the class. Student performance was measured using a publisher's multiple-choice test and a short answer test to assess knowledge about protein synthesis before instruction, immediately after instruction and one-month after instruction.

Data Analysis

Correlations were conducted for all of the subtests on the California Test of Basic Skills and achievement measures to determine if a relationship existed between background variables and posttest achievement. Multiple regressions were performed to determine the relative contribution of prior knowledge and treatment in predicting the posttest scores (both immediate and one-month).

Results

The first regression analysis in Table 1 on the immediate posttest produced an adjusted R square of .43. Forty-three percent of the variance for the immediate posttest was explained by the model. The pretest was significant in the equation. The California Test of Basic Skills (CTBS)-local percentile was also a significant predictor in the equation. Students with larger values of CTBS-local percentile tended to have higher scores on the immediate posttest.

Table 1

Multiple Regression with Immediate Posttest Score as Dependent Variable

Variable	Coefficient	Standard Error	Standard Coefficient	p
Constant	9.020	0.810	0.000	0.000
Biopretest	0.117	0.076	0.126	0.007*
CSI	0.004	0.003	0 .075	0.143
CTBSLP	0.040	0.007	0 .377	0.000*
T1 (Student)	0.153	0.453	0 .022	0.736
T2 (Teacher)	0.211	0.458	0 .031	0.645

Note. CTBS-local percentile and the Biopretest (biology pretest) were the two variables that contributed significantly to the posttest results. CSI= cognitive skill index,, T1=a dummy variable created for the student-generated group, T2= a dummy variable created for the teacher-generated group.

Two dummy variables gave an estimate of the predicted difference between treatment groups which controlled for at other variables in the equation. Controlling for the pretest scores and prior knowledge from the CTBS-local percentile scores seems to eliminate the difference between the treatment groups. The coefficients for the two dummy variables were not significant when controlling for the pretest and background knowledge, indicating that the difference between the treatment groups and control were not different from zero when prior knowledge is taken into account.

A second multiple regression analysis in Table 2 was done to assess the relationship between prior knowledge and the posttest score was taken one-month after instruction. Thirty-nine percent of the variance on the one-month posttest was explained by the regression model. Three predictor variables were significant in the analysis for the one-month posttest. The CTBS-local percentile score, the biology pretest and the student-generated treatment were significant predictors in the equation. Students with larger values of CTBS-local percentile tend to have higher scores on the one-month posttest. However, the dummy variable comparing the student-generated analogy group to the control group was significant. Even controlling for differences in background knowledge, the student-generated was predicted to score higher an average of .99 points higher than the control group on the 1-month posttest.

Table 2

Multiple Regression with the 1-Month Posttest as Dependent Variable

Variable	Coefficient	Standard Error	Standard Coefficient	p
Constant	6.108	0.913	0.000	0.000
Biopretest	0.205	0.086	0.149	0.018*
CSI	0.001	0.004	0.008	0.788
CTBSLP	0.037	0.008	0.238	0.000*
T1	0.221	0.050	0.107	0.050*
T2	0.350	0.516	0.045	0.498

Note. Biopretest (biology pretest), CSI (cognitive skill index), CTBSLP (California Test of Basic Skills-local percentile), T1 a dummy variable created for the student-generated group, T2 a dummy variable created for the teacher-generated group. * CTBS-LP and T 1 are significant predictors of the one-month posttest scores.

The relationship between prior subject matter knowledge and success with student-generated analogies is further supported by evidence from student interviews. These results suggest differences in metacognitive processing between the students who have minimal science knowledge from those that have more science knowledge.

Discussion

The results of this study indicate that prior knowledge was an important factor in the successful use of analogies. Multiple regression analyses were performed to examine the relationship between prior knowledge and posttest results. In both the immediate posttest and the one-month posttest, prior knowledge was a significant variable in predicting the student's performance on the posttests. In general, it seems as though the students who bring more general science background knowledge with them to science class benefit most from the instructional analogy approach.

This finding is also consistent with Alexander & Judy (1990) in that sixth graders who were low in knowledge of human biology benefited little from explicit instruction in the general strategy of analogical reasoning. They concluded that without basic competence in the content area, the training of using teacher-generated analogies as an effective strategy was not feasible.

The findings in this research regarding the importance of prior knowledge indicate that a foundation of science knowledge seems requisite to the efficient and effective use of not only teacher-generated analogies but <u>also</u> student-generated analogies. Alexander & Judy (1988), Newell (1980) and Resnick (1987) also claim that a certain amount of knowledge in the domain under study is necessary for the efficient use of strategic knowledge.

The students who bring more science background knowledge with them perform better using analogies. This could be explained by the fact that these students were bringing more knowledge to the task, therefore, having a better initial understanding of protein synthesis, and then freeing up resources for other tasks such as using analogies. Another explanation for the role of prior knowledge in analogy use may be that the students who have more prior knowledge find analogy use intellectually stimulating and may be more interested in the approach. These same students may have already been using analogies spontaneously and weren't cognizant of the fact that this was how they were learning.

The analysis of data raises some interesting questions for future research about the nature of analogies in the science classroom. It would be interesting to increase the length of intervention to determine whether or not student could be trained to use analogies spontaneously. If students could be trained to use them spontaneously, this method of instruction could have powerful implications for increasing the competency of science students. Also, differences between the teacher-generated and student-generated groups need to be explored in more detail, it was unclear whether one strategy was more effective than the other.

In summary, teachers should take pains to use analogies based on domains already familiar to the students and should make clear the semantic and structural correspondences between the analogs that are important for providing the desired explanation. Even if the teacher tries to use analogies to situations that familiar to the students, failures can arise because the students' knowledge is not in fact organized the way the teacher thinks it is.

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