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ABSTRACT

The purpose of this study was to assess the effectiveness of two generative learning strategies, concept maps and manipulation of objects, and to determine if either works better with individual learners or in cooperative learning groups. A total of 80 sixth-grade students in science education were randomly assigned to group or individual conditions and to one of the two experimental treatments. Experimental treatments were changed between first and second post-test. Long-term retention was evaluated with a third and delayed post-test. Students starting with concept maps showed higher achievement on delayed post-test than students beginning with manipulation of objects. No difference was found between students working as individuals or cooperative student teams. Furthermore, a significant interaction between generative learning strategy and grouping condition was revealed. Implications for sequencing generative learning strategies are discussed. (Author)

COMPARISON OF GENERATIVE LEARNING STRATEGIES

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Abstract

The purpose of this study was to assess the effectiveness of two generative learning strategies, concept maps and manipulation of objects, and to determine if either works better with individual learners or in cooperative learning groups. A total of 80 sixth-grade students in science education were randomly assigned to group or individual conditions and to one of the two experimental treatments. Experimental treatments were changed between first and second post-test. Long-term retention was evaluated with a third and delayed post-test. Students starting with concept maps showed higher achievement on delayed post-test than students beginning with manipulation of objects. No difference was found between students working as individuals or cooperative student teams. Furthermore, a significant interaction between generative learning strategy and grouping condition was revealed. Implications for sequencing generative learning strategies are discussed.

Introduction

"How can I help my student learn?"

The goal of increased student learning is a fundamental concern for teachers. Over the years, learning techniques and strategies have evolved as our understanding of learners, and how they acquire knowledge, has grown. From the 1950s to the early 1980s, much of the prevailing educational research focused on improving teaching by analyzing elements of *external* stimuli that formed the instructional environment. In the 1980s and 1990s, more energy was focused on identifying the processes that occur *internal* to the individual. Although many questions remain unresolved, countless educational researchers view learners as active participants in their learning, and believe that the role of a teacher should be to facilitate the learner's efforts to make meaning of their world (Jonassen, Beissner, & Yacci, 1993; Jonassen & Tessmer, 1996; Wittrock, 1974, 1990, 1991, 1992).

But how does a teacher facilitate knowledge acquisition? According to Osborne and Wittrock (1985), teachers need to provide opportunities for students to construct their own knowledge and to reflect on their freshly generated views. A common teaching strategy is to create an environment in which students analyze new material, provide opportunities for students to combine their new ideas with previously constructed knowledge, and facilitate student articulation on how the new information fits in with their existing mental structures. As this occurs, new mental structures are created, or existing structures clarified. The teacher's role then is to assist the students by providing additional information to either clarify the knowledge structure if misconceptions are obvious or to enrich, enlarge, and strengthen their newly developed mental structures.

Although students are continually going through the process of constructing and molding their knowledge networks, teachers often structure events to facilitate this process. Many of these activities have their roots in a learning theory originally articulated by Merlin Wittrock, known as generative learning theory (Grabowski, 1996; Wittrock, 1974).

Types of Generative Learning Strategies

The fundamental concept upon which generative learning strategies is based is that learning involves the creation and refinement of individual mental constructions of the world. Thus, facilitating that construction should be a primary concern for teachers. On the other hand, not all class work is considered generative in nature, even though it might help students build and clarify their conceptualization of the environment. Grabowski (1996) informs us that only those activities that involve the actual creation of relationships and meaning are classified as generative learning strategies, and that there are two basic families of these strategies.

One type of strategy is used to generate organizational relationships between different components of the environment, which helps a learner understand how items are related to one another. Well documented examples include creating titles, headings, questions, objectives, summaries, graphs, tables, and concept maps. On the periphery of this group is the manipulation of objects which some argue may also qualify as a generative strategy, "because a relationship is being drawn and extended between parts of the environment" (Grabowski, 1996, p. 911).

A second type of generative activity integrates relationships between external stimuli and memory. Examples include asking students to construct demonstrations, metaphors, analogies, examples, pictures, applications, paraphrases, or inferences. This group differs from the previous group in that these strategies not only require deeper processing of the instructional content, but they also result in a higher level of understanding.

Problem statement

Although generative strategies have been found to improve the effectiveness of learning (for a discussion of the studies on generative learning see Wittrock, 1992, or Grabowski, 1996), it cannot be assumed that all generative strategies work equally well under all conditions, and questions regarding the selection of appropriate strategies or how best to implement them are not yet sufficiently solved.

One question related to the instructional setting is whether students learn better as individuals or in groups. Kourilsky and Wittrock (1992) found that cooperative learning environments foster generative learning. Based on their study with 12th grade economics students, they reported that, "Cooperative learning appeared to provide an excellent context for students' discovery of one another's misconceptions and for the generation of alternative relations that better synthesize experience within the concepts of economics" (p. 874). However, the success of cooperative learning depends on effective small group interaction, which cannot be assumed for all groups. Hooper, Sales, and Rysavy (1994) replicated a study conducted by Wittrock and Alesandrini (1990) examining the effects of generative learning strategies on text comprehension. Hooper et al. attempted to extend the original study by investigating the effects of using a generative learning technique while studying alone or in small groups. Unexpectedly, they found that students working alone achieved better results on a posttest than students learning in groups. The researchers attributed this effect mostly to deficiencies in group interactions.

The instructional setting may influence the selection and effectiveness of appropriate generative learning strategies in other ways as well. For example, science and math teachers often face different requirements and challenges in terms of resources, classroom organization, etc. when conducting experiments that require specific apparatus as compared to traditional teaching activities. Under such conditions, the additional efforts can only be justified through improvements in the expected outcomes. As stated earlier, manipulating these sorts of objects may also qualify as a generative strategy and therefore justify the additional efforts, yet little research has been done in this area.

Sayeki, Ueno, and Nagasaka (1991) investigated the effectiveness of using a manipulative strategy to teach Japanese elementary students how to calculate the area of a parallelogram. The way students used the mediational objects appears to qualify as a generative learning strategy. Sayeki et al. reported that the use of the manipulatives increased students' comprehension of mathematical principles. Might it be possible, then, that manipulative activities can be truly considered generative, and successful in other content areas and for other types of learning outcomes? This question, along with the question of whether an individual or team approach works better for generative learning environments, became the driving forces of our study.

Purpose of Study and Hypotheses

The purpose of this study was to assess the effectiveness of two generative learning strategies, concept maps and manipulation of objects, with sixth-grade students, and to determine if either strategy works better with individual learners or groups of learners.

Two research hypotheses were generated:

- Based on the notion that the manipulative activity of completing a science experiment acts as a generative learning strategy, students who use this method will obtain criterion achievement scores equal to those of students developing concept maps on the same topic.
- Students who work in teams will score significantly higher on criterion achievement tests than students who work individually.

Methodology

Population and sample

The accessible population was sixth-grade science students enrolled in a middle school in San Diego, California. The cluster sample of 80 students included all sixth grade students at this school. Three students dropped out of the experiment between the second test and the delayed-post test.

Materials

A chapter from the Prentice Hall Science textbook *Exploring Earth Science* (Maton, Hopkins, Johnson, LaHart, Warner, & Wright, 1995) served as basis of the subject-matter content. Knowledge acquisition was measured by a 13-question multiple-choice test. Questions for the test came from the chapter test and additional questions were generated to match the content area. The classroom teacher worked with the researchers during the construction of the additional test questions, and verified the questions' face-validity.

Treatment and Procedure

Students were randomly assigned to one of four treatment groups using the class list and a table of random numbers. The groups included students working with concept maps in a team situation (CT), students working with concept maps individually (CI), students working with manipulatives in a team situation (MT), and students working with manipulatives individually (MI). Each of the four classrooms had approximately equal numbers of students in each of the four groups.

Each classroom participated in parallel instruction provided by the same teacher and textbook. At the conclusion of the first chapter segment (about 1/3 of the way through the chapter), students in the CT and CI groups were separated and moved to another room. There, they were given a blank sheet of paper. They were then asked to generate a concept map that describes nine characteristics of minerals (the topic they had just studied). All students were familiar with making concept maps as they had made numerous concept maps earlier in the school year. Students assigned to the CT group created the concept maps in teams of two or three students, while the students assigned to CI created concept maps individually.

Students assigned to groups MT and MI were separated and given a set of hardness points, a Moh's hardness scale table, a mineral color chart, and a set of six minerals. The students were asked to use the equipment and charts to identify each mineral sample. Students in MT performed the experiment in teams of two or three students, and students in MI conducted the experiment working individually. Students in all four groups (CT, CI, MT, and MI) were allowed to use the textbook as support material.

The following day all students were assessed on their knowledge of the content with use of the instrument described above.

At the conclusion of the chapter (10 days later), students who previously created concept maps were assigned to conduct the manipulatives experiment, and students who conducted the experiment created concept maps (the CT group switched activities with MT, and the CI group switched activities with MI). To allow testing of the second hypothesis, students who worked in teams during the initial activity continued to work in teams during the second activity (although they switched between concept mapping and manipulatives). The next day a chapter test was conducted, including the same questions as used during the initial quiz. Thirty-two days later all students completed a delayed posttest which was part of a larger unit test.

Results

Descriptive Statistics

The group names, number of individuals, means, and standard deviations of the results for each of the three tests are shown in Table 1. Note that the differences in the number of individuals (*n*) are caused by the variance in class size combined with variations due to using the table of random numbers.

Table 1. Descriptive statistics for the three tests

Group names based on first test	Test 1 (Following day)			Test 2 (10 days later)			Test 3 (32 days later)		
	n	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
Manipulatives, Teams (MT)	18	10.72	2.35	18	11.11	1.97	18	10.56	2.23
Concept Maps, Teams (CT)	22	11.95	1.25	22	12.05	1.00	21	12.14	1.11
Manipulatives, Individual (MI)	19	11.32	1.53	19	12.05	1.39	19	11.63	1.80
Concept Maps, Individual (CI)	21	10.9	1.58	21	11.05	1.47	19	11.47	1.78
Concept Maps, Total	43	11.44	1.50	43	11.56	1.74	40	11.82	1.48
Manipulatives, Total	37	11.03	1.97	37	11.56	1.33	37	11.11	2.07
Teams, Total	40	11.40	1.90	40	11.63	1.56	39	11.41	1.87
Individuals, Total	40	11.10	1.55	40	11.53	1.50	38	11.55	1.77

Inferential Statistics

The data were statistically analyzed using a 2 X 2 factorial analysis of variance (ANOVA), with a level of significance set at .10. The level of significance was set at .10 because little research has been done comparing generative learning strategies (therefore this could be considered an exploratory study) and we felt it better to make a Type 1 error than a Type 2 error. The two manipulated variables under study included the types of generative learning strategy (concept maps and manipulatives) and the method of instruction (individual and team). Besides comparing the initial test results, a secondary analysis was conducted to identify if any changes in long-term memory occurred that may have been dependent on the treatments.

The following charts report the F and p values from the three tests:

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Table 2. ANOVA table for Test 1

Variable	DF	Sum of Squares	Mean Square	F-Value	P-Value
Concept Map / Manipulatives	1	3.352	3.352	1.166	.2837
Team / Individual	1	1.034	1.034	.360	.5504
Concept Map / Manipulatives * Team / Individual	1	13.418	13.418	4.668	.0339
Residual	76	218.480	2.875		

Table 3. ANOVA table for Test 2

Variable	DF	Sum of Squares	Mean Square	F-Value	P-Value
Concept Map / Manipulatives	1	.25	.25	.011	.9150
Team / Individual	1	.016	.016	.007	.9323
Concept Map / Manipulatives * Team / Individual	1	18.688	18.688	8.627	.0044
Residual	76	164.632	2.166		

Table 4. ANOVA table for Test 3

Variable	DF	Sum of Squares	Mean Square	F-Value	P-Value
Concept Map / Manipulatives	1	9.802	9.802	3.192	.0781
Team / Individuals	1	.794	.794	.259	.6126
Concept Map / Manipulatives * Team / Individual	1	14.612	14.612	4.758	.0324
Residual	76	224.174	3.071		

Concept Maps and Manipulatives

For both Test 1 and Test 2, no significant difference was found between either of the two generative learning strategies (manipulatives and concept maps). This supports the first hypothesis that students engaged in a manipulative activity will achieve scores equal to those of students developing concept maps on a similar topic.

The delayed posttest, however, revealed a statistically significant difference between concept maps and manipulatives, $F(1,76) = 3.192, p<.10$. This result identifies a statistically significant difference in long-term retention scores among students who began with concept maps ($M = 11.82$) compared to students who initially worked with manipulatives ($M = 11.11$).

Individual Learning and Collaborative Learning

No significant differences were found among students who worked individually versus collaboratively in any of the three tests. This finding fails to support the second hypothesis that students who work in teams would score significantly higher than students who work individually.

Interaction between Strategies and Organization

For each of the three tests, the factorial ANOVA revealed a statistically significant interaction between concept maps/manipulatives and teams/individual. In Tests 1, 2, and 3, the respective F values were: $F(1,76) = 4.668, p<.10$; $F(1,76) = 8.627, p<.10$; $F(1,76) = 4.758, p<.10$. The graphs below display the interactions for each test.

Figure 1: Interaction Line Plot for Test 1

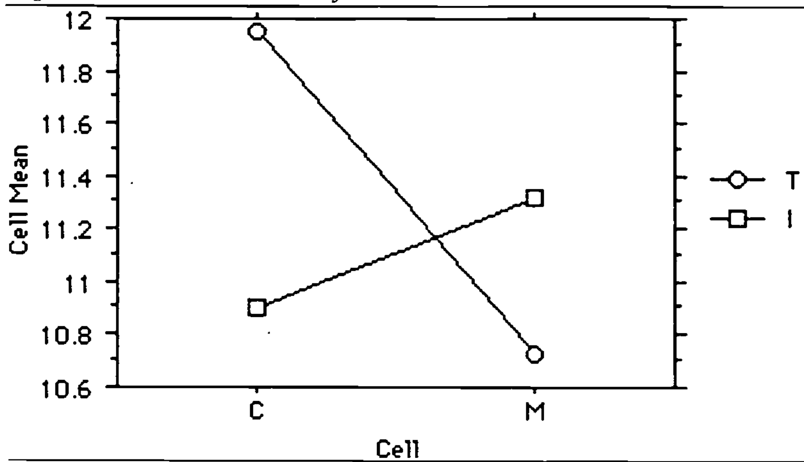


Figure 2: Interaction Line Plot for Test 2

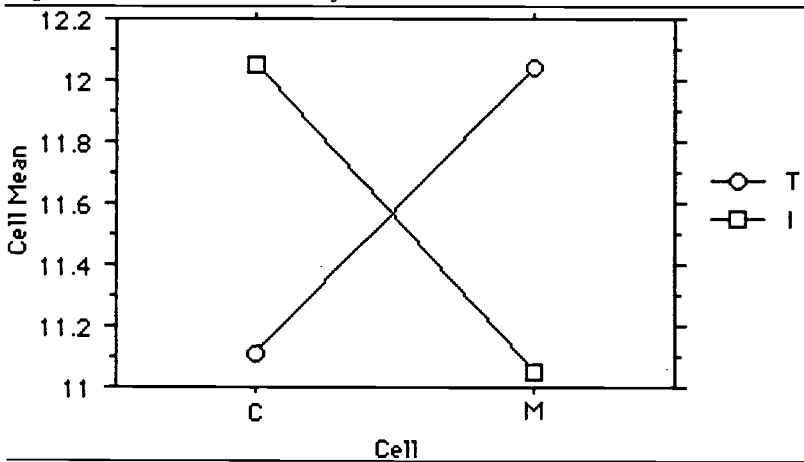
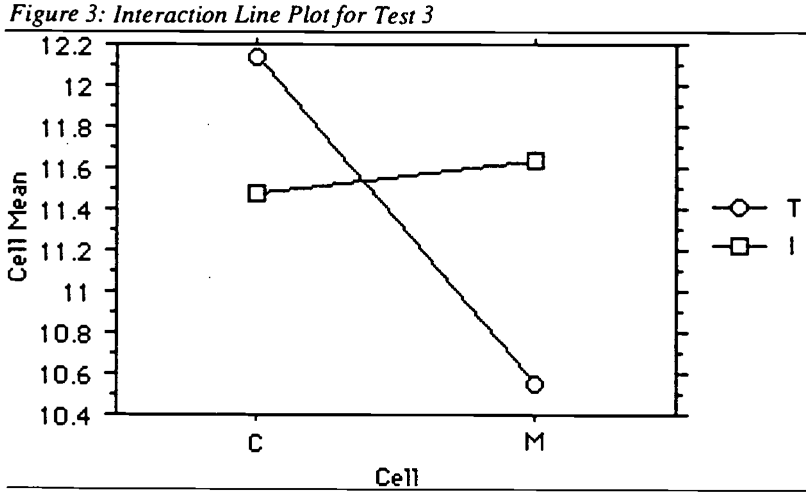


Figure 3: Interaction Line Plot for Test 3



Discussion

As mentioned earlier, the study verified our first hypothesis in the first and second test—that students engaged in a manipulative activity will achieve scores equal to those of students developing concept maps on a similar topic. This lends support that, at least in this case, the two strategies work equally well. When the equality of strategies is added to the idea that the manipulation of mediational objects is helping learners to create mental relationships and meaning between knowledge components, it supports the idea that manipulation of items may be considered a generative learning strategy.

The study failed to confirm the second hypothesis (i.e., students learn better in teams than as individuals). Interestingly, when these two variables were analyzed together, we found statistically significant interactions between the generative learning strategies (concept maps and manipulative experiments) and the classroom organization (individuals and teams) for each of the three tests.

These treatment interactions cannot be easily explained because they seem to be in reverse order between Test 1 and Test 2. For example, on the first test teams creating concept maps (CT) showed higher mean scores (M = 11.95) than their counterparts in the manipulative groups (MT) (M = 10.72). But in the second test, teams conducting the manipulative experiments (MT) achieved higher mean scores (M = 12.05) than teams creating concept maps (CT) (M = 11.11). Because the same group of students outscored the other group no matter the generative strategy imposed, this led us to originally conclude that the results might be better explained by parameters such as pre-test performance, general aptitude, or student learning style than by the experimental treatments. However, the delayed posttest yielded a treatment interaction again, but this time in combination with a significant difference between mean scores achieved by students working on concept maps (M = 11.82) versus students engaged in the manipulative experiments (M = 11.11).

Before we present what we consider a potentially noteworthy finding, we feel it important to acknowledge the limitations of the study. Our finding could simply be a consequence of the experimental design, which may not have addressed all threats to external validity (i.e. multiple treatment interaction). Another limitation was that although all students were in the class for the instruction, there was a difference in information imparted between the test sessions, and this difference may have influenced student scores. Additionally, it can be said that students may not have received enough specific instruction regarding collaborative learning techniques. This reminds us of the study of Hooper, Sales, and Rysavy (1994) who pointed out that one cannot simply assume that effective small group interaction occurs naturally without teacher's guidance.

A more tantalizing explanation is that the sequence of generative learning strategies may be responsible for the differences we found. Students who started with concept maps and then switched to manipulative experiments retained information better than those who started with experiments and then did concept maps. Interestingly, the mean scores of students who started with concept maps were higher on the delayed post-test than on their first test, whereas the mean scores of students who started with manipulative experiments were lower on the delayed post-test than on the initial test.

These results appear to indicate that creating concept maps prior to engaging in manipulative experiments produces better long-term retention than the opposite sequence. Or to over generalize for a moment, better results are found when teachers use more inclusive, encompassing, or general activities before specific or concrete activities. This finding supports Reigeluth's elaboration theory (English & Reigeluth 1996; Reigeluth, 1983), which claims that it is important to explicitly state the overall structure of the content before getting into the details. Elaboration theory proposes a simple-to-complex sequence "with the most essential information presented in advance of more complex and detailed information" (Jonassen, Beissner, & Yacci, 1993, p. 116).

Why does the sequence make a difference? Translated to the framework of this study, one could argue that the students' mental models achieved during the concept map activity were more expansive than mental models achieved while the students were focusing on the details during the manipulative experiment. Thus, learners creating concept maps first may have established a better network to which they attached the small chunks of information encountered later during the manipulative experiment.

Contrarily, doing the concrete activity first (i.e., the manipulative experiment), some of the facts may have seemed disassociated with the other pieces; or—to say it metaphorically—students couldn't see the forest for the trees. They learned little things, but didn't get the big picture. Grasping the big picture first through the use of concept maps provided the expansive view, to which they attached the individual facts when they did the experimental activity.

In conducting the literature review for this study, we were only able to identify one previous study that examined the sequence of generative learning strategies in regards to knowledge acquisition. In a study investigating the effects of generative strategies on reading comprehension, Linden and Wittrock (1981) compared sequences of learner activities that proceeded from imaginal to verbal generations with sequences of activities in the reverse order. They concluded in their study that the sequence wasn't critical, and that "...it seems that the generation of text-relevant associations, in either order, was the more important factor in enhancing comprehension in this study" (Linden and Wittrock, 1981, p. 55). However, with the results of this study indicating that sequence is important, and recent explorations into learning proposed by the elaboration theory, further inquiry into this topic is warranted.

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