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AUTHOR	BouJaoude, Saouma; Tamim, Rana	
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ABSTRACT

Generative learning strategies are the focus of the study described in this paper. Research questions pertain to the effect of practice in the generation of analogies and summaries by Grade 7 students on their achievement in science, the different types and numbers of analogies that students generate, and students' perceptions of the effectiveness and utility of the generative learning strategies. Results indicate that there are no significant differences among students' scores in the categories of analogy generation, generation of summaries, and read-and-answer questions. Three possible reasons why the analogies and summaries did not work very well with the subjects of this study are also discussed. Those reasons include: the concurrent use of multiple strategies, an inherent discrepancy between the generative and traditional means of assessment, and inadequate time for the activities. Contains 44 references. (DDR)

Analogies, Summaries, and Question Answering in Middle School Life Science: Effect on Achievement and Perceptions of Instructional Value

Saouma BouJaoude & Rana Tamim
Science and Math Education Center, American University of Beirut

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Conceptual and meaningful understanding of science is indispensable if we are to prepare citizens capable of proper decision making regarding science related issues (Knamiller, 1984). Rote learning is inadequate and students are expected to understand central concepts as well as relationships between concepts in many disciplines (Gardner & Boix-Mansella, 1994). Meaningful understanding will help students use knowledge in novel situations, develop coherent networks of concepts, use what they learn in school to understand the world around them, and develop a lifelong interest in intellectual pursuit (Simmons, 1994).

For years, however, evidence has been mounting that present systems of science education are not working well (Lee & Anderson, 1993). The emphasis on rote learning is a major reason. It seems that teachers stress the acquisition of factual information and tests are usually direct assessments of memory tasks and performance skills (White, 1985), with little emphasis on meaning or sense making (Cavallo, 1991).

Generative learning has been found to help students to learn meaningfully in different subject areas. It is believed to influence students' concept acquisition by affecting generation of links between prior knowledge and new experiences. Moreover, it is believed to motivate students by actively involving them in the learning process as well as helping them to correct their alternative conceptions (BouJaoude, 1992). Generation of analogies and summaries, two generative learning strategies, has been found to enhance achievement and stimulate students' analytic and holistic abilities (Wittrock & Alesandrini, 1990). However, most of the research on generative strategies was conducted at the university level and in areas other than science. Consequently, the research questions that guided the present study were the following:

Research question 1: What is the effect of practice in the generation of analogies and summaries by Grade 7 students on their achievement in science, in comparison to reading and answering questions? We hypothesized that the use of generative learning strategies (generation of analogies, and generation of summaries) will enhance science achievement as measured by a posttest containing higher cognitive level questions. Furthermore, we expected the generation of summaries to have a larger impact on students' science achievement than the generation of analogies (Wittrock & Alesandrini, 1990).

Research question 2: What are the different types and numbers of analogies that students generate?

Research question 3: What are students' perceptions of the effectiveness and utility of these learning strategies?

Background

Rote learning is described as the learning of new information through the use of memorization. It signifies the absence of connections between new and previously acquired information. Because new information is not anchored to existing concepts in the learner's mind, it is easily forgotten (Anderson & Ausubel, 1966). Rote learning destroys the connectedness and meaningfulness of science (Cavallo, 1991). In contrast, meaningful learning, described by Ausubel (1968) as the establishment of non-arbitrary relations among concepts in the learners mind, is the fundamental process which underlies the acquisition of useful information and the construction of new knowledge (Novak, 1990). Perkins (1994) states that students who "see the connections" (p. 84) are more likely to understand and remember what they learn. Also, they are thought to have a greater ability to correct misunderstandings and to solve problems through the use of the relations they construct between the new knowledge and the relevant concepts they already possess. By creating meaningful links, learners are able to organize the information in bigger, more organized chunks of information, and thus reduce their memory overload and increase their processing capacity. They are able to increase the amount of information they can process simultaneously, ultimately improving their ability to solve problems (BouJaoude, 1992).

Some researchers argue that students who learn meaningfully may not achieve the highest grades on traditional school tests (Cavallo, 1991). Thus it is important to note that to teach for understanding requires that teachers closely attend to assessment by keeping it an ongoing component of instruction (Simmons, 1994), and by tapping secondary aspects of knowledge besides memory aspects, such as ability of knowledge transfer and problem solving (White, 1985).

Use of analogies

Instructional analogies are instances where a less familiar domain is made understandable by referring to similarity relations with a more meaningful domain. They provide a bridge between what is known and what is less known (Dagher, 1995a). In this study, we refer to the domain which acts as a base or source in the teaching or learning as an "analog" while the explained domain is referred to as a "target" (Duit, 1991). In other research studies, the "analog" is referred to as source, base, anchor, and vehicle (Dagher, 1995a).

Science teachers use different types of analogies in their teaching. Dagher (1995b) found that seventh and eighth grade science teachers use five different types of analogies that she labeled compound analogies, narrative analogies, procedural analogies, peripheral analogies, and simple analogies. Analogies assist in conceptual change (Dagher, 1994; Duit, 1991), facilitate understanding of abstract notions by pointing to similarities in the real world, provide visualization of the abstract, provoke students' interest and thus motivate them, and force the teacher to take students' prior knowledge into consideration (Duit, 1991). In addition, analogies act as comprehension and memory aids in reading texts, facilitate learning and understanding (Halpern, Hansen, & Riefer, 1990; Vosniadou & Schommer, 1988; Wong, 1993a), produce higher achievement at Bloom's application level (Maharisi, 1984), and may help reveal alternative conceptions (Duit, 1991; Wong, 1993a). Gibbs and Lawson (1992), and Lawson (1993) suggest that the use of analogies by science teachers helps students in concept acquisition and the development of scientific reasoning skills. Finally, Clement (1993), found that the use of bridging analogies[1] help students in constructive thinking and understanding.

In addition to the use of analogies by teachers, researchers have investigated the effect of self-generated analogies on a variety of variables. Results of research in this area have shown that students who generate analogies develop critical thinking and problem solving skills (Middleton, 1991), have better understanding of the textual material (Wittrock & Alesandrini, 1990), and change their understanding of scientific phenomena by providing new explanations or asking important questions about these phenomena (Wong, 1993a). Wong concluded that the generation of analogies helps learners to make new situations familiar, represent problems by using prior knowledge, and to stimulate abstract thinking about underlying structures. Furthermore, Wong (1993b), found that self-generated analogies stimulate new students' inferences and insight and help them control the generative capacity of their own analogies to advance their understanding of conceptual phenomena.

Use of analogies is not a simple process, however. Clement (1988) identified four processes which appear to be important in the use of analogies: generating the analogy,

[1] A bridging analogy is an intermediate analogy that shares features with the original case and the analogous case.

establishing confidence in the validity of the analogy relation, understanding the analogous case, and applying findings to the original problem. Furthermore, Dagher (1995a) suggests that "Meaningful learning via instructional analogies is not a function of whether an analogy is used as much as it is a function of how it is actually used (in text, presentation, or discussion), by whom, with whom, and consequently how it is evaluated." (p.23)

While research on the effect of using analogies on students' learning and thinking skills and on students' attitudes toward using analogies provides support for using them in the classroom, Wong (1993a), notes that there is limited research on the effect of the generation of analogies by middle school students on their meaningful learning of science.

Summarization

Recently, educational researchers have paid increasing attention to summarization. Doctorow, Wittrock, and Marks (1978) suggest that students' generation of summarizing sentences increases the generative processing in memory. The summary writer must decide what to include, what to eliminate, how to reorganize information, and to ensure that the summary is true to the original meaning (Hidi & Anderson, 1986; Anderson & Hidi, 1989). Hidi and Anderson (1986), conceive of two types of thinking, selection and reduction, as needed for summarization. Moreover, they suggest that the characteristics of the text, the presence or absence of the text while summarizing, and the purposes of the summary itself are factors that influence the process of summarization.

Research on the use of summaries has shown that undergraduate students with high summarizing efficiency recognized true-to-text synthesis statements, which did not appear in the original text. Yet, they failed to strongly reject statements inconsistent with low importance-in-text information (Garner, 1982). Brown and Day (1983) found that fifth graders know how to delete trivial or redundant elements of simple texts while older high school and college students were more able to use more complex condensation rules, such as invention and integration. Moreover, they found that experts (rhetoric teachers) outperformed freshman college students in their ability to combine information across paragraphs and in their ability to provide a synopsis in their own words.

Wittrock and Alesandrini (1990), compared the effects of analogy and summary generation by undergraduate students on their analytic and holistic abilities upon learning a block of a fifty-paragraph text. Results of this study indicated that in the generation of summaries treatment, both the holistic and analytic abilities correlated with learning, while in the generation of analogies treatment, only the analytic ability did. The same system of generative summarization was used by King (1992) to compare self questioning, summarizing, and note taking-review as strategies for learning from lectures for under-prepared college students. Results showed that at immediate testing, summarizers remembered more of lecture content than self questioners, who in turn performed significantly better than note taking-reviewers. But on a retention test administered one week later, self questioners performed somewhat better than summarizers who significantly outperformed note taking-reviewers.

In general, summarization has been found to enhance comprehension and recall of passage content (Brown & Day, 1983; Reinhart, Stahl, & Erickson, 1986; Ross & DiVesta, 1976; Wittrock & Alesandrini, 1990). Generative summarization in particular has not been widely investigated as a strategy for understanding and remembering scientific information. In the middle school, there is an absence of studies in this area, even though many practicing teachers encourage students at all levels to use summarization during studying.

Question Answering

Answering questions has been found to improve students' achievement. It is thought that engaging students in answering thought-provoking questions or in generating them will help them gain the knowledge and skills necessary for managing their own learning. Results of research have shown that questions designed to promote connections within the lesson and questions intended to access prior knowledge and promote connections between the lesson and that knowledge induced complex knowledge construction. However, questions designed to access prior knowledge were more effective in enhancing learning (King, 1994); elaborative interrogation, a strategy dependent on question answering, helped sixth and seventh graders to perform significantly better than reading controls, across all memory measures (Woloshyn, Paivio, & Pressley, 1994). Moreover, students who generated their own questions outperformed those who used experimenter generated ones (Foos, Mora, & Tkacz, 1994) and the use of orienting questions helped students to activate concept-relevant prior knowledge and anticipatory perspectives which aid in both the selection and integration of knowledge (Osman & Hannafin, 1994)

Methods

Sample

The sample consisted of 51 students (25 males and 26 females) from the Grade 7 class in a private school in Beirut where English is the language of instruction. The average age of the students was twelve years. Two sections participated in the experiment. Both sections had the same science teacher. The students in each section were randomly assigned to three groups, X, Y, and Z.

Tasks and materials

1. Science Unit: The title of the science unit during which the study took place was Interactions of living things. This unit consisted of three sections: a) interactions within the environment, (b) niches and adaptations, and (c) changes and balance in the food web.

2. Instruction booklets: Booklets containing specific instructions for a specific learning strategy (generate analogies, generate summaries, and read-and-answer-questions) were designed specifically for this study. Figure 1 provides an example of the instruction booklets used in the study.

Figure 1: Instruction Booklet for the generation of summaries

Name: ______________________________

In the space below provide a summary for the assigned material.

Remember the rules:

- Ignore the information which is not important.
- Combine similar information in groups or categories and provide a label.
- Select a main idea sentence if there is one.
- Invent a main idea sentence if it is missing.

3. Science achievement tests: The achievement tests used in this study were prepared according to a table of specifications by the investigators and the science teacher to make sure that the style of the questions and the language used were clear to the students. To reflect a higher level of meaningful learning, test items were prepared at different cognitive levels of Bloom's taxonomy of educational objectives. This strategy assured that the tests were assessing meaningful learning (Lehman, Carter, & Kahle, 1985; Willerman & Mac Harg, 1991). A math educator and the investigators checked the achievement tests to ensure that the items matched the instructional objectives and the cognitive levels specified in the table of specifications. The correspondence between the math educator and the two investigators on the first posttest was 87%, on the second posttest 90%, and on the third posttest 73%. The internal consistency reliability for the three tests was moderate. For the first test the reliability was 0.5, for the second it was 0.6 and for the third it was 0.4. To pilot the tests, three Grade 7

students from a different school were asked to read the tests and comment on their clarity. Comments of the three students were taken into consideration.

4. Perceptions questionnaire: A questionnaire consisting of five open-ended questions was designed to investigate students' perceptions of the effectiveness and utility of the three learning strategies. At the end of the experiment, students were asked to fill out a questionnaire surveying their perceptions of the effectiveness and utility of the learning strategies.

Independent and Dependent variables

The independent variables in this study were the generation of analogies and the generation of summaries. The dependent variables in this study were students' achievement on the posttest and their feelings towards the learning strategies.

Procedure

All members of the sample participated in three 50-minute training periods. The first training period introduced the process of generation of analogies and generation of summaries to the students through the presentation of the guidelines required for these processes. In the case of analogy generation, a vocabulary worksheet adapted from Middleton (1991) was used, while the students' generation of summaries was guided by four rules adapted from Brown and Day (1980, cited in Casazza, 1993). The second and third training periods gave the students the chance to practice the two strategies by using biology topics selected from their own textbook. During the third period answering questions was also practiced.

1. training (3 periods)
2. 5 periods
5 periods
5 periods

After the training periods, the science teacher covered the normal biology program with her usual teaching method. The experiment included three phases. In each phase, one of the three biology sections was covered. Each section took around 4 to 5 class periods. At the end of each class period, students were given approximately 10 minutes to fill out an analogy worksheet, or generate a summary, or read-and-answer-questions. The three groups in each class worked at the same time, each on a different strategy, under the supervision of the researcher and the teacher who made sure that students did not interact with each other. Students were asked to write their analogies and summaries and answers to questions in an instruction booklet designed specifically for this purpose (Figure 1). All booklets were collected at the end of each period, checked by one of the investigators, corrected, and returned to the students at the beginning of the next class period. The checked booklets included written feedback concerning the students' analogies, summaries, and answers. The feedback was written in cases where the analogies were not clear and needed extra

this is only for summaries

explanations, or when the summaries were long or included redundant information. Students were instructed to read the feedback on their work before writing the new set of analogies, summaries or answers. Before returning each set of booklets to the students, a photocopy was kept with the researcher for future analysis. At the end of each section, a posttest including high level items was administered[2]. During each phase of the experiment, each group was assigned a different learning strategy in such a manner that the three groups had the chance to work with the three learning strategies (Table 1).

Table 1.

Design of the experiment

Group	X from both sections	Y from both sections	Z from both sections
Phase 1	Generate Analogies	Generate Summaries	Read and Answer Questions
Phase 2	Generate Summaries	Read and Answer Questions	Generate Analogies
Phase 3	Read and Answer Questions	Generate Analogies	Generate Summaries

Data Analysis

A one way analysis of variance (ANOVA) was used to test the presence of a statistically significant difference among the three groups at each phase of the study at an alpha level of 0.05. Since no significant differences were found among the groups, no post hoc procedures were used to test the differences between the individual groups.

The types and numbers of analogies generated by the students were analyzed to investigate which type/types were used most frequently. The analogies were grouped under four types based on the nature of the analog. Data from the questionnaires were analyzed using the process of analytic induction (Bogdan & Biklen, 1982; Goetz & LeCompte, 1984). This process involved scanning the responses for categories and relationships among categories, and "developing working typologies and hypotheses upon examination of initial cases, then modifying and refining them on the basis of subsequent cases" (Goetz & LeCompte, 1984, p. 180). Categorization of the analogies was conducted by the investigators and a science education graduate student. During the analysis, an initial set of analogies was categorized by the investigators and the science education graduate student to reach consensus on the type of categories. Then, each of them analyzed the rest of the data independently. At

[2] The first test was announced, while the second and third tests were not announced

the end of the analysis the two investigators and the graduate students met to resolve any differences and reach consensus about all categories.

Results

Achievement on the Posttests

In the first phase of the experiment, group X was assigned the analogies strategy, group Y the summaries strategy, and group Z the answering questions strategy. Table 2[3] shows the means and standard deviations of the students' total achievement scores, and their achievement scores on the items at the comprehension level and above in the first posttest. The means of the total scores on the achievement tests ranged from 72.73 for the students using the generation of summaries strategy to 73.89 for the read-and-answer-questions, while the means of scores on the comprehension items and above ranged from 70.77 on the generation of analogies strategy to 71.64 for the read-and-answer-questions strategy.

The standard deviation for students' total scores ranged from 11.00 for the read-and-answer-questions strategy to 11.56 for the generation of summaries strategy. Whereas the standard deviation for students' scores on the comprehension items and above ranged from 11.29 for the generation of analogies strategy to 14.17 for the generation of summaries strategy.

Table 2.

Means and Standard Deviations for Students' Total Achievement and Achievement at the Comprehension Level and Above on the First Posttest.

	N	Mean (Total)	Standard Deviation	Mean (Complus)	Standard Deviation
Summary	17	72.73	11.56	68.40	14.17
Analogy	15	73.75	11.05	70.77	11.29
Question	17	73.89	11.00	71.64	14.00
Total	49				

In the second phase of the experiment, group X was assigned the summaries strategy, group Y the read-and-answer-questions strategy, and group Z the analogies strategy. Table 3

[3] In Tables 2, 3, and 4 "Total" represents students' scores on all test items and "Complus" represents students' scores on the test items at the comprehension level and above. Both are reported out of 100.

presents the means and the standard deviations of the students' total achievement as well as their achievement on the items at the comprehension level or above in the second posttest. The means of the total scores on the achievement tests ranged from 62.44 for the read-and-answer-questions strategy to 65.88 on the generation of analogies strategy, while the means of the scores on the items on comprehension and above ranged from 55.37 for the read-and-answer-questions strategy to 56.74 for the generation of analogies strategy.

The standard deviation for students' total scores ranged from 11.32 for the generation of analogies strategy to 14.75 for read-and-answer-questions strategy. Whereas the standard deviation for students' scores on the comprehension items and above ranged from 13. 86 for the generation of analogies strategy to 19.24 for the read-and-answer-questions strategy.

Table 3.

Means and Standard Deviations for Students' Total Achievement and Achievement at the Comprehension Level and Above on the Second Posttest.

	N	Mean (Total)	Standard Deviation	Mean (Complus)	Standard Deviation
Summary	17	64.71	12.65	56.35	14.69
Analogy	17	65.88	11.32	56.74	13.86
Question	16	62.44	14.75	55.37	19.24
Total	50				

In the third phase of the experiment, group X was assigned the read-and-answer-questions strategy, group Y the analogies strategy, and group Z the summaries strategies. Means and standard deviations of the total scores and the scores on the items at the comprehension level or above in the third posttest are reported in Table 4. The means of the total scores on the achievement tests ranged from 70.19 for the generation of analogies strategy to 74.47 for the generation of summaries, while the means of the scores on the items on comprehension and above ranged from 64.70 for the generation of analogies strategy to 67.68 for the read-and-answer-questions strategy.

The standard deviation for students' total scores ranged from 10.02 for the generation of analogies strategy to 14.45 for the read-and-answer-questions strategy. Whereas the standard deviation for students' scores on the comprehension items and above ranged from

10.92 for the generation of analogies strategy to 15.01 for the read-and-answer-questions strategy.

Table 4.

Means and Standard Deviations for Students' Total Achievement and Achievement at the Comprehension Level and Above on the Third Posttest

	N	Mean (Total)	Standard Deviation	Mean (Complus)	Standard Deviation
Summary	17	74.47	11.16	66.77	14.97
Analogy	16	70.19	10.02	64.70	10.92
Question	17	72.77	14.45	67.68	15.01
Total	50				

It is worth noting that in the two posttests where the students did not expect to be tested (posttests two and three), the standard deviation for the students' total achievement and their achievement at the comprehension level and above was lowest for the groups that practiced generation of analogies and highest with the groups that practiced the read-and-answer-questions strategy.

It is also noticed that the mean of the total scores on the first posttest was higher than the mean of the total scores on the second posttest, while the mean of the total scores on the third posttest was higher than the mean of the total scores on the second posttest.

A one-way analysis of variance (ANOVA) was used to analyze the data from the three posttests. A separate analysis was done for each phase, one for the total scores and one for the scores on the items at the comprehension level or above. The raw scores were used in the statistical analysis. There were no significant differences among the groups at the 0.05 level of significance. Consequently, it can be concluded that the science achievement of students using a generative learning strategy (generation of analogies or summaries) is the same as the achievement of students who use the read-and-answer-questions strategy and the science achievement of students using the generation of analogies strategy is the same as the achievement of the students using the generation of summaries strategy.

Types and Numbers of Analogies

The analogies provided by the students during the three phases of the experiment were classified into four types based on the nature of the analog (Middelton, 1991). The four types of analogs were: 1) everyday structure; 2) everyday process; 3) scientific term, structure; 4) scientific term, process. The analogies were classified by the investigators and a science education graduate student. When the classifications were compared, there was an 88.2% agreement (410 out of 500 analogies). The investigators and the science education graduate student resolved the differences and reached total agreement on the categorization.

Analogies classified under everyday structure included those that compared a scientific term with an everyday life object or structure that looks like or has the same physical property of the term. For example, if enzyme was compared to a jigsaw puzzle, if a dragonfly was compared to a helicopter, or if blood circulation was compared to a subway system, the analogy was placed in this category.

Analogies classified under everyday processes included those that compared a scientific term to an action or process that is encountered in everyday life. For example, if transpiration was compared to water going up through a straw, if plants were compared to a food factory, or if the heart was compared to a pump or a beating drum, the analogy was placed in this category.

Analogies classified under scientific term--structure, included those which compared the scientific term to another scientific term which has the same structure. For example, if the atom was compared to the solar system, or if monera were compared to protists (both are microscopic), the analogy was placed in this category.

Finally, analogies classified under scientific term--process, included those which compared two scientific terms that had similar processes or functions. For example, if the nucleus of a cell was compared to the brain (both are controlling centers), or if bacteria were compared to fungi (both could be decomposers), the analogy was placed in this category.

The number of analogies provided by the students during the three phases of the experiment was 500. In addition, the students provided 51 entries which could not be classified as analogies. The numbers and percentages of analogies at each level are reported in Table 5. Tables 6, 7, 8, and 9[4] present examples of each category of analogies and Table 10 presents examples of the responses that were not categorized as analogies.

[4] S followed by a number refers to a student's number

Table 5.

Numbers and Percentages of Student-Generated Analogies.

	Type 1: Everyday structure	Type 2: Everyday-process	Type 3: Science-term--structure	Type 4: Science-term--process	Non-Analogy
Number	146	206	37	111	51
%	26.5%	37.4%	6.7%	20.1%	9.2%

Table 6.

Examples of Analogies that use an Everyday Structure

	Vocabulary term	Is like	How?
S1	population (same species)	money in the bank	each type of money is in a different place
S13	population (same species)	army	army has soldiers of the same nationality
S14	environment	classroom	both surround living and non-living things
S14	community	library	include different organisms or books
S47	front teeth	chisel	both have the same shape
S29	hawk	eagle	both very similar in shape
S21	food web	spider web	all the strings are connected together
S9	food chain	circle	both have the same shape
S35	teeth	prison	nothing can go out

Table 7.

Examples of Analogies that use an Everyday Process

	Vocabulary term	Is like	How?
S2	leaves of trees	skin color	in summer, leaves turn red, we get tanned
S1	populations competing	runners in a race	both competing for first place
S13	representative sample	senator	one represents population and one represents his country
S17	change in population	balance	remove weight from one arm, the other arm changes
S13	ecosystem	football team	depend on whatever is in the ecosystem or group
S14	food producer	support in a building	one is the basis for the food chain, and the other for the building
S40	eyelids	car window cleaners	both wipe and clean
S13	sample	identification card	both give information about something or someone

Table 8.

Examples of Analogies that use a Science Term Structure

	Vocabulary term	Is like	How?
S13	organism	matter	both made of tiny things, atoms or cells
S5	pond	lake	both hold water, and both are ecosystems
S41	niche	population	both are systems and ways of classification
S40	skin	thin crust of the earth	both are covering layers
S19	stem of a plant	spinal cord	both are long and sensitive
S29	food web	community	both include many groups
S16	snake	snail	both have no feet
S38	fingernails	shell of cricket	both are hard coverings

Table 9.

Examples of Analogies that use a Science Term Process

	Vocabulary term	Is like	How?
S2	environment	solar system	planets surround the sun and influence each other, environment surrounds the organism
S8	community	energy pyramid	different animals are interacting in both
S17	community	human body	interaction among many parts
S49	food	fuel	provide energy to different things to help move and work
S48	pitcher plant	digestive system	both digest food particles
S40	eyes	magnifying glass	both magnify
S21	plants	algae	both produce food
S34	grasshopper	spring	both push down to have an upward force
S32	energy	electricity	energy moves from one organism to the other, electricity moves from one appliance to the other
S18	decaying	recycling	in both cases, things are made available to be used once again
S43	omnivore	carnivore	both eat meat
S40	skin	crust of the earth	both provide protection

Table 10.

Examples of Responses not Categorized as Analogies.

	Vocabulary term	Is like	How?
S40	cats	children	love each other
S36	front teeth	cutters	eat apples
S30	lion	claws	to catch prey
S15	area	place	a place for living

Perceptions questionnaire

The five questions included in the perceptions questionnaire were:

1. Which one of the learning strategies did you like most? (Analogies, summaries or answering questions), and why?

2. Do you feel that any of the strategies helped you understand the science lesson more? If yes, which one and why, if no, why?

3. Which of the strategies would you use if the teacher didn't ask you to? Why?

4. Do you feel that the three strategies can be used with subjects other than science? If yes, which method, with which subject and why? If no, why?

5. Would you like to learn other similar strategies? Why?

Students' Preferences for Learning Strategies

The results of analyzing students' responses to Question 1 are presented in Table 11 which shows that approximately 41% of the students preferred the read-and-answer-questions strategy, followed by analogies (33.3%), and summaries (11.8%). Also, Table 11 shows that a number of students preferred a combination of strategies. For example, almost 6% of the students said that they liked both analogies and the read-and-answer-questions strategy.

Table 11.

Students' Preferences of Learning Strategies.

Analogies	Summaries	Answering questions	Analogies & questions	Summaries & questions	Summaries & analogies	All three strategies
33.3%	11.8%	41.2%	5.9%	3.9%	2.0%	2.0%

Reasons for Students' Preferences of Strategies:

Generation of analogies:

The most common reason for preferring analogies was that analogies were interesting (6 students out of 17; 35.3%[5]). The second most common reason was that they helped students to study by comparing things from different domains (4 students out of 17; 23.5%). The third reason was that they were easy (4 students out of 17; 23.5%). The fourth reason was that analogies were new (2 students out of 17; 11.8%). Finally, 2 students out of 17 (11.8%) said that analogies made studying easy.

The most common reason for choosing summaries was that they stressed the main idea and the important concepts (3 students out of 6; 50%). The second reason was that summaries helped in studying and understanding the lesson (2 students out of 6; 33.3%). The third reason was that they helped in organizing information (1 student out of 6; 16.7%). The final reason was that they helped in understanding the lesson and may still include both analogies and questions (1 student out of 6; 16.7%).

Read-and-answer-questions

The most common reason for choosing the read-and-answer-questions strategy was that this strategy was easy (15 students out of 20; 75%). The second most common reason was that it needed little time (8 students out of 21; 38.1%). The third most common reason was its ability to help students pick what to include in the answer (3 students out of 21; 14.3%). Another reason for choosing the read-and-answer-questions strategy was familiarity with the strategy (2 students out of 21; 9.5%). Finally, 2 students out of 21 (9.5%) said that the read-and-answer-questions strategy helped them to check their understanding of science content.

Combinations of strategies

Students who preferred combinations of strategies had similar reasons to the ones given for preferring particular strategies. The three students who chose analogies and questions said that they were either easy or new while the two students who picked summaries and questions suggested that the two strategies captured the main idea of a paragraph and were helpful. The student who picked summaries and analogies said that analogies appeared suddenly when she studied. She also said that summaries helped her to understand new

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[5] Some students provided more than one reason for liking a given strategy, thus the sum of the percentages for the reasons could be more than 100.

material while analogies helped her to compare what she was studying with other familiar things. Finally, the student who said the three were enjoyable asserted that analogies were fun, questions were easy, and summaries were useful.

When students' preferences were analyzed across all the strategies, it was found that they preferred questions because they were easy, analogies because they were fun, and summaries because they helped them to capture the main idea in the lesson.

Strategies as Support for Understanding Science Lessons

Results of analysis of students' responses to Question 2 are presented in Table 12 which shows that most students chose the generation of summaries (39.2%) and reading and answering questions (21.6%) in response to this question. It is worth noting that 23.5% of the students said that none of the strategies helped them understand science lessons better.

Table 12.

Students' Perceptions of the Most Helpful Strategies.

Analogies	Summaries	Answering questions	Summaries & questions	All three strategies	None
5.9%	39.2%	21.6%	3.9%	3.9%	23.5%

Reasons for Students' Preferences

Generation of analogies

The reason that was reported by students for choosing analogies as the most helpful was that analogies helped them understand and memorize by relating different ideas (3 students out of 3; 100%).

Generation of Summaries

Students who thought summaries were the most helpful had different reasons for their responses. The most common reason was that summaries included the main idea of the lesson or paragraph which made the lesson shorter (13 students out of 20; 65.0%). The second reason was that summaries helped students understand all the lesson (4 students out of 20; 20.0%). Other reasons included the fact that writing a summary was an easy way of studying to achieve high grades and that summaries helped in checking what has been studied .

Read-and-answer-questions strategy

The most common reasons for choosing the read-and-answer-questions strategy as the most helpful was that questions helped in preparing for exams (5 students out of 11; 45.5%).

Other reasons included the fact that the read-and answer questions strategy helped to improve grades and that it was straightforward and interesting.

Combinations of strategies

The reason for choosing both generation of summaries and the read-and-answer-questions strategy as the helpful strategies was that they helped in studying and understanding (2 students out of 2; 100%).

Finally, The students (23.5%) who felt that none of the strategies were helpful mentioned different reasons. The most common reason was the shortage of time (4 students out of 12; 33.3%):

The overall responses to this question show that summaries were considered helpful because they made lessons shorter, analogies because they helped to relate science to daily life, and read-and-answer questions because they provided a practical method for checking understanding before an exam.

Using the Strategies Without Teacher's Advice

Results of analyzing students' responses to Question 3 are reported in Table 13 which shows that approximately one third of the students would use the read-and-answer questions strategy, while 27.4% said that they would use summaries, and 17.6% said that they would use analogies without the teacher's advice.

Table 13.

Students' Preference of the Strategy to be Used Without Teacher's Advice.

Analogies	Summaries	Questions	Analogies & questions	Summaries & questions	Summaries & analogies	All three strategies	None
17.6%	27.4%	33.3%	2.0%	5.9%	5.9%	2.0%	3.9%

Reasons for Students' Choices

Generation of analogies

The main reason for choosing analogies was that they were interesting (4 students out of 9; 44.4%) followed by analogies being easy (3 students out of 9; 33.3%). Other reasons included: analogies did not need a lot of time (3 students out of 9; 33.3%), helped students understand and memorize new terms (2 students out of 9; 22.2%), and were new (2 students out of 9; 22.2%).

Generation of summaries

The students who picked summaries had different reasons. The first reason was that summaries provided a short lesson and thus a shorter time to study (3 students out of 14;

21.4%). A second reason was that summaries were familiar (3 students out of 14; 21.4%). Other reasons included: summaries provided better understanding of the material (3 students out of 14; 21.4%), summaries helped checking understanding (2 students out of 14; 14.3%).

Read-and-answer-questions

Students who chose to use the read-and-answer-questions strategy on their own chose it because it was simple and did not need a lot of time. Seven students said questions were easy (7 students out of 17; 41.2%) and three students mentioned that they can be answered quickly (3 students out of 17; 17.6%). Other reasons included: questions helped in reviewing for exams (5 students out of 17; 29.4%) and questions were practical and familiar (2 students out of 17; 11.8%).

Combination of strategies

The reason that made one student choose analogies and questions was that questions were related to key terms while analogies helped in remembering the different terms. The students who chose summaries and questions said that summaries provided the main idea while questions helped provide answers (1 student out of 3; 33.3%) and summaries provided the main ideas while questions helped for checking understanding (1 student out of 3; 33.3%).

The three students who chose summaries and analogies said that summaries and analogies helped in understanding and relating ideas (1 student), summaries helped in understanding the whole lesson while analogies helped in understanding new terms (1 student), and summaries summed-up the lesson while analogies were fun (1 student out of 3; 33.3%). Finally, the students who reported that she would use the three methods suggested that were helpful and convenient.

For this question, the students' responses reflected a personal preference for the use of questions because they were familiar, while the use of summaries was preferred because it made the lesson short. As for analogies, they were picked because they were interesting.

Using the Strategies in Subjects Other than Science

Results of the analysis of Question 4 are reported in Table 14 which shows that 35.3% of the students selected summaries and questions, 23.5% selected all three strategies, and 15.7% selected summaries. Only a small percentage of students selected analogies and summaries and 13.7% selected none of the strategies.

Table 14.

Students' Perceptions of the Applicability of the Strategies in Other Subjects.

Analogies	Summaries	Questions	Summaries & questions	All three strategies	None
3.9%	15.7%	3.9%	35.3%	23.5%	13.7%

Of the students who said analogies were useful when studying other subjects, one student felt that they were useful with English and Arabic only, and one student felt they were useful with all other subjects. Moreover, of the students who thought that summaries were useful when studying other subjects, 37.5% (3 students out of 8) felt that they were useful when studying social studies, 25.0% (2 students out of 8) felt that they were useful when studying Arabic, and 87.5% (7 students out of 8) felt that they were useful when studying English.

Of the two students who said that questions were useful when studying other subjects, one felt that they were useful when studying English while the other felt that they were useful when studying both English and Arabic.

The responses to Question 4 show that students valued summaries and questions more than analogies because analogies did not seem to work with subject areas other than science. Still, the three strategies were considered to be helpful with the English language, while very few students mentioned the relevance of these strategies with mathematics.

Willingness to Learn Other Strategies

In response to Question 5, 66.7% of the students said they were ready to learn other strategies while 33.3% said they were not. The students who agreed to learn other strategies suggested that these strategies might help them in studying better (23 students out of 34, 68%) and simplify studying (4 students out of 34, 12%). Each of the remaining students (20%) gave a different reason for his or her answer. One student thought that such methods could help him if he became a teacher in the future. Another student said that she was willing to do anything that helped her learn and improve in her studies. A third student noted that he was ready to learn new strategies only, since the ones he worked with were already known to him. A fourth student said that he wanted to learn new strategies because he was always curious about new things while the fifth said that he was ready to learn new strategies because of their potential usefulness in the future. A sixth student said that, while he would like to learn new strategies, school work was too time consuming to allow for such a thing to happen.

The seventeen students (33.3%) who were not ready to learn other strategies said that these methods were not helpful and were a waste of time.

In this question, the high percentage of students who said that they were willing to learn other strategies is impressive. However, responses of certain students reflected the importance of the time required to become proficient in using such strategies along with the effect of the new strategies on their grades.

Discussion and Recommendations

When students' scores on the posttests were analyzed, there were no significant differences among students' scores in the three groups, generation of analogies, generation of summaries, and read-and- answer-questions. These results reflect the failure of the two generative learning strategies to increase students' achievement on the posttests. This failure was not anticipated. Wittrock and Alesandrini (1990) showed that generation of analogies by students correlated with their analytic ability, while the generation of summaries correlated with both their analytic and holistic abilities. Furthermore, they confirmed that the use of generative learning strategies increased students' achievement on posttests that were administered directly after the treatment and showed that students who generated summaries scored two points higher than those who generated analogies. These two points were not considered as a significant difference. However, Wittrock and Alesandrini worked with undergraduate students and their findings do not seem to apply to middle school students.

Why didn't the analogies and summaries work as well with the students in this study as they did with the students in Wittrock's and Alesandrini's study? There are three possible reasons for this discrepancy.

First, it could be that students used the three strategies at the same time while studying the material on their own for the first test, especially that the practice sessions included training in using the three different learning strategies and students had time to prepare for the test. Besides, students are usually test-oriented. They neglect any strategy which, in their opinion, is not fruitful or conducive for higher grades (Briscoe & LaMaster, 1991). This was reflected clearly in the students' responses in the perceptions questionnaire. Consequently, they might have used the strategy that worked best for them, and hence their performance was not significantly different on the first test. On the second and third tests, however, the students did not have time to study on their own. Still the results were not significantly different. Thus, it can be argued that the three strategies were equally effective especially that the average was relatively high on both of these exams.

Second, the lack of significant differences among the groups could be due to the inherent discrepancy between generative learning and traditional methods of assessment such as the ones used in this research. Tests used in this study, like other teacher made tests, test material that is considered either correct or incorrect while generative learning strategies are supposed to help students construct their own understandings of concepts. Therefore students may have constructed understandings about the concepts in the lessons that are not exactly those in the tests. Also, tests may not have reflected the type of learning enhanced by generating analogies and summaries.

Third, it can be argued that the ten minutes provided at the end of each class period for a limited number of days during the experiment was not enough for the students to think through their responses and relate these responses meaningfully to the subject matter they were studying. Novak (1990) states that a certain pattern of achievement is often noted when instructional strategies requiring meaningful learning are used. For two to three weeks, a general average decline in the performance on exams is seen. Score averages then start moving up, usually finishing significantly higher for students using some meaningful learning tools or strategies. However, in this study, there was no decline in achievement scores.

In conclusion, it can be said that there is no conclusive evidence to suggest that generation of analogies and summaries is more effective in improving performance on achievement tests designed to measure higher cognitive levels. Yet, it seems that the generation of analogies, the generation of summaries, and the read-and-answer questions strategy produced acceptable levels of achievement in all situations.

Results supported previous research findings concerning students' ability to generate analogies at different levels of association. The number of analogies generated during the three phases of the study was impressive (500 analogies, approximately 10 analogies per student). This finding supports Middelton's (1991) opinion concerning student-generated analogies in biology, and Wong's (1993) findings regarding self-generated analogies. The large number of student-generated analogies compiled in this research study reflect a well developed student ability to formulate links between prior knowledge and new information.

Moreover, the analogies generated by the students provided an insight concerning which level is generated more frequently. The highest percentage was for analogies comparing a science term to a process that the students observe in their daily lives (37.4%). While the lowest percentage was for analogies comparing a science term with another science term that has the same structure (6.7%). This finding may have important instructional implications regarding the integration of students' classroom and everyday experiences in science teaching. Future research investigating the influence of each level of analogies on students' meaningful learning could be more informative concerning which level of analogies is more effective with students.

Students' preferences concerning the three strategies balanced out, where each of the strategies was valued by a group of students for a specific reason. The read-and-answer-questions strategy was mainly preferred for being familiar and requiring little time and effort from the students. Generation of summaries was preferred mainly for being helpful in studying, while generation of analogies was preferred because it was interesting and entertaining. Nevertheless, some students reflected an interest in doing well on tests and considered the generative learning strategies to be a waste of time especially that, in their opinion, these strategies do not help them to get better grades on tests.

Students' preference for the read-and-answer-questions strategy is understandable. Students usually invest the least effort to reach their goal, and prefer whatever is easy and familiar for them. However, an interesting finding in the present study was that despite the failure of the two strategies in effecting students' achievement on the posttests, students did value their generative effect. Some students felt that generation of analogies was helpful in understanding new terms, while most of the students who preferred analogies thought that they were an interesting way of studying. Other students believed that generation of summaries helped them understand and organize the information to be studied.

Implications for Science Teaching and Research

The large number of analogies generated by the students points out that they can link different ideas and concepts. Students are constantly building new concepts through linking them with prior knowledge. By encouraging analogy generation, teachers would be building up a skill that is not that foreign to students. Moreover, many students felt that generation of analogies was an interesting way to study science, consequently generation of analogies may be used to make science more interesting to students. The higher percentage of analogies using everyday processes analogs reflects a higher probability of students' understanding the association between science and everyday life. Teachers could use such information to their advantage when they are providing analogies to the students.

Students' positive attitude toward the generation of summaries should be taken into consideration by the teachers. Helping students to develop proper summarizing skills will be effective even if the findings of this study do not reflect any gains on the achievement tests. This is supported by the students' responses on the perceptions questionnaire.

Although researchers seem to believe that the use of generative learning strategies improves students' achievement on tests assessing meaningful learning, the findings of this study do not support this belief. However, there is need for more research on this topic to reach more valid outcomes. First, research remains to be done on the effect of prolonged practice of these generative strategies on students' meaningful learning of science. Second, alternative methods of assessment which comply with the constructivists' ideas and assess meaningful learning should be developed, tested, and employed in future research.

Moreover, there may be developmental factors that influence students' benefit from generative learning strategies, consequently there is need for research in this area, especially that most of the published research on the effect of analogies on achievement was conducted with older students. Finally, there is a need to conduct research on what types of analogies influence achievement.

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