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THE INFLUENCE OF USING ANALOGIES IN INSTRUCTION ON STUDENTS' LEARNING

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ABSTRACT

THE INFLUENCE OF USING ANALOGIES IN INSTRUCTION ON STUDENTS' LEARNING

By

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Analogical reasoning and the influence of analogies on learning were researched extensively in the past twenty years. Nevertheless, there is little research regarding the effectiveness of analogies in an instructional setting and no research on how analogies influence students' learning in an instructional setting.

Therefore this study focused on two questions:

1. Does the use of an analogy in instruction help students to learn a scientific principle better than instruction without an analogy?
2. How does the use of an analogy in instruction influence students' learning?

I used tutoring to teach college students one of two lessons about human physiology. Students answered interview questions to assess their recall and understanding of the targeted principles. Immediately after the interview, students saw a videotape of their interview and were asked to describe their thinking processes before they answered each question.

I conducted a follow-up second experiment using the same procedures. However, this time I removed the illustrations from the lesson, and the interview was conducted one week, not two days, after instruction. I conducted a quantitative analysis to answer the first question of the study and a qualitative analysis to answer the second. Results show that: 1. There were no significant differences in overall interview scores between Analogy and No Analogy groups. Removing illustrations from instruction and assessing students' performances after a longer period favored the analogy group. 2. Students' scores, comments, and opinions suggest that analogies facilitated students' recall (by providing cues to recall the relevant information in the target principle), but it did not facilitate students' comprehension.

The successful implementation of analogies in instruction depends on careful consideration of several factors: targeted domain difficulty, students' familiarity with the analogy, other instructional material used in instruction, and how and when students' performance is assessed. In this study, analogies fell short on demonstrating their usefulness in improving students' understanding. There is evidence that they improved recall and influenced students' reasoning in subtle ways that may not show in an overall assessment of students' performance.

DEDICATION

To My beloved Mother,
My Dear Wife Muna,
My Daughters Bodoor And Afnan, My Son Ahmed,
And To The Memory Of My Father

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INTRODUCTION

Learning new scientific principles and concepts is a challenging task. To meaningfully understand a scientific phenomenon, the learner must incorporate the new information using what he already knows (Glynn & Duit, 1995). Furthermore, research on science learning suggests that learners have intuitive explanations of scientific phenomena that may not be compatible with the scientifically acceptable explanations. These intuitive explanations, called misconceptions, add to the difficulty of understanding scientific principles and concepts because they are highly robust and may outlive instruction (Viennot, 1979).

One possible approach for meaningfully teaching scientific ideas is the use of analogies. Analogies advance learners' understanding of scientific principles by utilizing what the learners are familiar with. Posner, Strike, Hewson, and Gertzog (1982), said that "Any available metaphors, models, and analogies should be used to make a new conception more intelligible and plausible" (p.223). Furthermore, analogies do not only facilitate the learning of new concepts, they also help learners develop a new perspective for what they already know (Duit, 1991). As a result, analogies are often recommended as an important teaching

strategy, especially in the field of science (Mayer, 1983; Lawson, 1993).

Given the importance of analogies in science learning, analogical reasoning and the influence of analogies on learning were researched extensively in the past twenty years. Nevertheless, there is little research regarding the effectiveness and the role of analogies in an instructional setting that involves a teaching situation between a student and a teacher. As I will demonstrate in the following literature review, most research on analogies' effectiveness were conducted by asking students to read written passages, with and without analogies, and did not involve an interaction with a teacher. What is more important is that there is no research on 'how' analogies influence students' learning in an instructional setting.

Thus, the objective of this study is to answer the following two questions:

1. Does the use of an analogy in instruction help students learn a scientific principle better than instruction without an analogy?
2. How does the use of an analogy in instruction influence students' learning?

In this study I will address these two issues in an effort to enhance our understanding of the role of analogies in the learning process. The following is a review of previous research and theoretical work relevant to this study.

CHAPTER 1:

LITERATURE REVIEW

The purpose of this review is to discuss the following in relation to this study to be able to formulate this study's questions, hypotheses, and rationale:

1. Literature about how can analogies influence learning.
2. Theories regarding the dynamics of reasoning by analogies.
3. Models and recommendations for presenting analogies in instruction.
4. The depth and breadth of the research base on the use of analogies in instruction.

Before proceeding to the different sections of this review I will explain briefly what is an analogy, clarify some terminology that will appear in the next sections, and discuss some aspects of the analogies I used in this study.

What is an Analogy?

An analogy is an explicit, nonliteral comparison between two things in which their structural, functional, and/or causal similarities, and sometimes their differences, are described (Newby & Stepich, 1990). Tierney and Cunningham (1984) define analogies as "An expositional method for comparing sets of information which are similar enough in essential respects to permit transportation of attributes

across sets, usually from familiar to unfamiliar information" (p.613). Newby and Stepich explained that an analogy is composed of four parts: Target (something new), Connector (e.g., is like), Vehicle (something known called also base, analog, and source), and Ground (similarities and differences).

In the present study I used two analogies in the context of two lessons. The first analogy can be summarized in the following statement:

> Insulin decreases glucose level by increasing the number of glucose transporters like the emigration supervisors who decreased the number of people in the emigration area by calling additional emigration officers.

The second analogy can be summarized in the following satement:

> The Hypothalamus keeps a stable body temperature like the air condition thermostat that keeps the temperature of a room stable.

The two analogies can be classified in terms of the nature of relationship between the target and vehicle as functional analogies. In functional analogies the vehicle and target share a similar function (Curtis & Reigeluth, 1984). In addition, the two analogies can be classified as enriched analogies (Thiele & Treagust, 1994), because statements of the shared attributes are included in the instruction.

I have chosen these two analogies because I think that students are familiar with the vehicles I used in them. In the first analogy I used the airport emigration as the vehicle to teach students about how the body controls the level of sugar in blood. I believe that stusents are familiar with the emigration situation because kuwaities travel a lot, and I expect that most students are familiar with the airport emigration. In the second analogy I used the thermostat to teach students about how body controls its temperature. I expected that students are familiar with the thermostat because the thermostat and how it works is taught in high school. In addition, thermostat is part of the central air conditioning, the primary cooling device at kuwaities' homes. I will turn now to the four sections of this review.

Analogies and Learning

In recent years, educators have emphasized that learning is an active constructive process as opposed to passive enlargements of knowledge (Duit, 1991). According to constructivists' view, learning involves the interpretation of new information in terms of the learner's existing knowledge (Von Glaserfeld, 1987). Students use their knowledge, sometimes called schema (Gick & Holyoak, 1983; Stepich & Newby, 1988), as a framework within which subsequent related information is organized and understood.

Learning by analogies enables students to use their prior knowledge to make new information familiar. An analogy

relates the new information to what the student already knows; therefore, the new information acquires meaning and becomes familiar (Glynn, Duit, & Thiele 1995; Reigeluth & Stein, 1988).

According to Rumelhart and Normann (1981), an analogy accomplishes this by focusing on one or more salient characteristics of the thing to be learned and finding something already familiar to the learner that has similar structural, functional or causal characteristics. It then establishes an "is like" relationship between the two things by describing their resemblance or similarities.

Analogies are also emphasized as a central mechanism for conceptual change (Suzuki, 1994). Posner, Strike, Hewson, and Gertzog (1982) presented an approach to conceptual change that is based on contemporary views on philosophy of science (e.g., Kuhn, 1970). They recommended the use of analogies as a strategy for conceptual change because they will make a new conception more intelligible and plausible. Brown (1993) argued that analogies help to enrich and concretize the problem situation which leads to conceptual change.

Vosniadou and Brewer (1987) said: "In our view there are two candidate mechanisms for the kind of radical restructuring that may occur in children's acquisition of domains .. Socratic dialogues and analogies, metaphors, and physical models" (p.61).

Furthermore, analogies not only facilitate the learning of new concepts, they also help learners develop a new

perspective for what they already know: "Using an analogy is essentially a two-way process involving developing both analog and target" (Duit, 1991, p.653).

On the other hand, analogies are described as "double-edged swords" that may cause the formation of misconceptions (Glynn et al, 1995). Webb (1985) cited the growing body of literature which indicates that analogies are not always effective aids of learning. An analogy can produce misconceptions if students are not aware of the points where analogies break down.

Zook (1991) presented a model for predicting the likelihood of analogical misrepresentation based on the interaction of two factors: locus of generation (learner-generated or teacher-generated) and the component analogical process (selection of the analogy or mapping between the vehicle and target). Zook suggested that (a) selection difficulties increase the potential for misrepresentation under learner-generated analogies, and (b) mapping difficulties increase the potential of misrepresentation under teacher-generated analogies. When learners create the analogy they may face difficulties in selecting or coming up with an appropriate familiar domain that shares enough attributes with the targeted domain. On the other hand, when the analogy is presented by a teacher or text, learners may face difficulties on deciding which features of the familiar domain are relevant to the targeted domain. Thus, learners

may map information from the familiar domain to the target domain incorrectly.

In addition, Dagher (1994) reviewed three recent studies that dealt with teaching analogies to aid conceptual change (Dupin & Johsua, 1989; Treagust et al. in press; Brown & Clement, 1989). Dagher used Chi (1992) two types of conceptual change; 'normal' and 'radical' to characterize the contribution of using analogies in instruction on conceptual change. Normal conceptual change involves reorganizational shifts *within* three ontological categories, matter, events, and abstraction. Radical conceptual change involves shifts *across* the three ontological categories. Dagher concluded that there is a modest contribution of analogies to normal conceptual change, and recommended investigating the role of analogies in promoting creativity and positive attitudes.

From the above, there are two main themes on the potential influence of analogies on students' learning. One theme argues favorably for the use of analogies to promote learning. The other, points to the negative or limited role of using analogies in promoting students' learning. Hence, one question of this study is how effective the use of analogies in instruction in promoting students' learning.

Reasoning by Analogies

Analogical reasoning research is concerned with studying the mental processes that underlie learning by analogy. Central to understanding these processes is explaining the mapping process from the vehicle to the target that occurs

when people reason analogically. Through mapping the similarities between the vehicle and target are detected and the relevant information in the target is inferred (Mason, 1994). According to Gentner (1989) "an analogy is a mapping of knowledge from one domain (the vehicle) into another (the target), which conveys that a system of relations that holds among the vehicle objects also holds among the target objects" (p.201).

Mason (1994) suggested that there are three major theories about how analogical mapping occurs: componential, structural, and pragmatic. The componential theory is limited to analogical reasoning in the classical four element comparisons of the form a:b::c:d. The structure-mapping theory (Gentner, 1983) proposed that a system of procedures and rules, that are based on the syntactic features of knowledge, governs the mapping process. On the other hand, the pragmatic theory emphasize that mapping is governed by the goals of the learner not by cold syntactic features of knowledge representation. The following is a description of each theory:

a. Componential theory: Sternberg (1982) identified the different component skills that underlie reasoning by analogy involved in the classical four element comparisons of the form a:b::c:d. (e.g., car: fuel::Human:?). Sternberg suggested six components involved in this kind of analogical reasoning: 1. encoding the analogy, 2. inferring the relation between (a) and (b), 3. mapping the relation

between (a) and (c), 4. applying an analogous relation between (b) and the unknown term to find (d), 5. justifying the match between (b) and (d), and 6. making the response.

b. Structural theory: Gentner (1989) suggested a system of procedures based on syntactic features of knowledge. Gentner proposed a process of analogical reasoning that consists of five subprocesses: 1. accessing the base, 2. performing mapping between target and base, 3. evaluating the match, 4. storing inferences in the target, and 5. extracting commonalties. Gentner introduced the concept of systematicity as a central feature of the mapping process: people are inclined to map connected systems of relations organized by higher-order relations rather than mapping isolated elements.

c. Pragmatic theory: In this theory the goal of the information processing system is emphasized (Gick & Holyoak, 1983; Holyoak and Koh, 1987). "The mapping of information from a source to a target is heavily influenced by the system's goal. Different goals can lead to different mappings for the same analogy. Even the perception of the structure of an analogy is affected by the pragmatic context of its use" (Mason, 1994, p.159). Holyoak (1987) argued that analogical reasoning involves four basic steps:

1. Constructing mental representation of vehicle and target.
2. Selecting the vehicle as a potentially relevant analog to the target.

3. Mapping the elements of the vehicle and target.
4. Extending the mapping to generate a solution to target.

I find Holyoak's four-step model to be particularly useful because it starts by emphasizing the ability of the learner to mentally represent both the target and the vehicle. The necessity of thinking about both parts of the analogy at the same time and recognizing the relationship between the two hint to the suggestion that an analogy is a two-way process (Duit, 1991). Not only does the vehicle facilitate the learning of the target, but the target also improves the understanding of the vehicle.

In addition, the last step of Holyoak's model highlights the problem solving capacity of analogies. Learners use analogies to generate solutions, make explanations, and forecast predictions (Gentner & Gentner, 1983; Wong; 1993). This is a central proposition of this study. Two thirds of the questions that I used to assess students' learning in this study required students to make explanations or predictions and therefore emphasized the problem-solving aspect of using analogies in instruction.

More importantly, I used the mapping theory to derive two of the hypotheses of this study. These hypotheses are related to how analogies are going to influence students' recall and understanding of instruction. I hypothesized that analogies will influence recall by providing cues which will help in remembering the targeted information (Stepich & Newby, 1988). The learner will recall the element(s) in the

vehicle part of the analogy and map it to its equivalent in the target, so the information in the vehicle become cues to recall the equivalent information in the target. I also hypothesized that analogies will influence students' understanding in the following way: through the mapping process students will use the relationships between the different elements in the vehicle to infer equivalent relationships in the target. Therefore, the vehicle part of the analogy will enable students to formulate specific explanations and predictions regarding the target part of the analogy (Gentner & Gentner, 1983).

Presenting Analogies in Instruction

Several models and recommendations are suggested for presenting analogies in instruction. Newby and Stepich (1987) prescribed six steps for constructing and presenting analogies to students:

1. Decide whether to use an analogy (depending on the difficulty of the concept to be presented).
2. Construct the analogy by first identifying salient features of the targeted concept; then find something from the learner's prior knowledge that shares these attributes; and finally, clearly describe the similarities between the two.
3. Decide the presentation format (verbal, pictorial, or both).
4. Present the analogy early in instruction.

5. Explain where the analogy works and where it breaks down.
6. Use analogy in practice and provide corrective feedback.

After analyzing science textbooks ranging from elementary to college level, and after analyzing the lessons of ten exemplary middle and elementary school teachers, Glynn, Duit, and Thiele (1995) concluded that both authors and teachers used six operations to teach with analogies. These operations were then summarized and called Glynn's Teaching With Analogies Model (TWA). These steps should be used when teaching with analogies:

1. Introduce the target.
2. Cue retrieval of the analog (vehicle) concept.
3. Identify relevant features of the target and analog.
4. Map similarities.
5. Indicate where the analogy breaks down.
6. Draw conclusions.

Harrison and Treagust (1993) used classroom observation, audiotaped recordings, and teacher and students interviews to evaluate the effectiveness of Glynn's TWA model in a regular classroom. They reported their observation of a lesson about the refraction of light presented by a tenth-grade teacher using an analogy. The results demonstrated that a competent teacher can implement this approach successfully in the classroom "provided adequate in-service education is given, there is an opportunity for collegial support, and time is available for and reflective feedback." (p.1305)

In this study I used most of the steps mentioned in Glynn's TWA model to present analogies in instruction. I started by introducing the target principles to students (step one); then I presented the vehicle to them (step two); after that, I worked with the students to make them identify the relevant features and map the similarities between the vehicle and the target (step three and four). I did not discuss with the students where the analogy would break down (step five).

In addition, past research emphasized that students must be explicitly directed to make the connection between the vehicle and the target domain (Gick & Holyoak, 1983) and that students themselves should make the mapping between the vehicle and the target (Duit, 1991). I applied both recommendations in the instruction I used to present analogies to the students in this study. Toward the end of instruction, I asked the students to explain to me the targeted principle using a comparison between the vehicle and the target. This explicitly directed the students to make the connection between the vehicle and the target and encouraged them to make the mapping between the two domains.

In this study I used interactive tutoring (see the method section for details) to teach each student about one of two scientific principles. Merill defined principles as "explanations or predictions of why things happen in the world. Principles are those cause-and-effect or

correlational relationships that are used to interpret events or circumstances" (See in Reigeluth, 1983).

The first principle explains how insulin regulates the glucose level in the blood. The second principle explains how the hypothalamus regulates the body temperature. In the first principle the dependent variable is the level of glucose in blood. The independent variables are the amount of food eaten, and the level of insulin in blood.

For simplicity I called the first topic the Insulin lesson and the second topic the Hypothalamus lesson, in reference to a central element in the target process. I have chosen these two topics because I think they provide an adequate level of difficulty and complexity to the undergraduate students which justify the use of analogies.

Research on Analogies' Effectiveness

The research regarding the influence of using analogies in instruction can be divided into two areas: (a) the influence of using analogies in text on students' performance, and (b) the influence of using analogies in instruction on students' performance. The first area is extensively researched. Studies I discuss here are those which are closely related to this study. The second area analogies' effectiveness in instruction is much less researched as I will explain later.

Analogies' Effectiveness in Text

Although the results of these studies depend on certain conditions, they point out that including analogies in text has a positive effect on student performance. Table 1 presents an overview of the studies about the effectiveness of using analogies in text. The classification I used here is adapted from Dagher (1995).

The results of these studies can be summarized in the following:

1. Analogies have more positive influence on delayed recall than immediate recall and more positive influence on comprehension questions than recall questions.

Radford (1989) found that analogies are probably more useful in improving delayed recall than improving immediate recall. He found that including analogies in text significantly increased high school students delayed recall of two biology passages. Yet, significant differences on the immediate recall test were found in only one passage of the two used in the study. This indicates that analogies are more useful in improving delayed recall. In contrast, Simons (1984) conducted two experiments in which he investigated the effect of using analogies in text on students' immediate and delayed recall. In the first experiment, Simons found no significant differences in either the immediate posttests or the long term retention tests between the analogy and control groups. In the second experiment, Simons found a significant

Table 1

Overview of Empirical Studies about the Effectiveness of Analogies when Used in Text or Instruction.

Authors	Date	Type	Assessment	Results	Context
Bean et al	1985	E	Matching test	P/C	Text
Donnelly & McDaniel	1993	E	Multiple choice, and cued recall	P/C	Text
Gilbert	1989	E	Multiple choice short answer, and attitude scale	N/A-	Text
Irizarry	1990	E	Multiple choice and attitude questionnaire	P/A+	Text
Radford	1989	E	Multiple choice	P/C	Text
Simons	1984	E	Multiple choice	P	Text
Wiesenberg	1990	E	Multiple choice and a questionnaire	P/C	Text
Clement	1993	E	Multiple choice and observations	P	Instruction
Dupin & Johsua	1989	D	Observations and interviews	P	Instruction
Gable & Sherood	1980	E	Multiple choice	N	Instruction

D= Descriptive study, E= Experimental study.
P= Positive effect, N= No difference, C= Conditional, A-= negative Attitudes, A+= positive Attitudes.

difference in the immediate recall test in favor of the analogy group, and no significant difference on the long term retention test. The results of the second experiment indicate that analogies are more helpful in immediate recall.

Donnelly and McDaniel (1993) found that including analogies in text helped students to answer only inferential-type questions but hindered performance on recall-type questions. They explained this result by indicating that because students had to think about the vehicle (more information), analogies distracted students' attention from the targeted concept. However, in this study the students' performance was assessed directly after reading the passages. This means that the recall assessed here is immediate recall, which may support the finding in Radford's study mentioned above, i.e., that analogies are less effective in improving immediate recall.

Gilbert (1989) found that using analogies, similes, and metaphors in two biology units for ninth and tenth grade students did not increase students' scores in achievement tests that stressed recall, comprehension, and application. In fact, there was an indication of negative effect on students' attitudes. Yet, similar to Donnelly and McDaniel's study, students were assessed in the same day after reading the instructional units. Therefore, recall assessed in this study is immediate recall, also.

From the above studies, analogies have different effects on different studies. However, there is indication that

analogies used in text can improve delayed recall and comprehension (inferential) questions. In the present study I assessed students' performance in both recall and comprehension. This is because recall and comprehension are important learning outcomes and because past research provided mixed results regarding the influence of analogies on these two learning outcomes. Thus, I wanted to investigate the influence of using analogies on both types of questions.

In this study Comprehension is further divided into two categories: explanation and prediction. I did this because students' ability to explain and predict situations related to the targeted principle are good indicators of students' comprehension. The following is an explanation of the three question categories I used to assess students' learning:

Explanation. In an explanation question I stated to the student a new situation and the result of some unknown action, and asked him to state the likely cause and explain his answer. To answer an explanation question the student must state the quality or quantity of the likely cause and state how the principle is being used to find that cause (Yelon, 1989). An example of an explanation question in the insulin lesson would be: Why do we feel tired (the result of some unknown action) after a period of not eating (new situation)? Why (explanation)? To answer this question the student must state that the cause of this is an insufficient glucose level in the blood or in the cells, and that glucose is a source of energy to the nerve and muscle cells

(statement of the likely cause), and state that since glucose comes from the digestion of food, a period of fasting therefore will cause a drop in the level of glucose in the blood (statement of how the principle is used).

Prediction. In a prediction question I stated or described to the student a new situation and asked him to state the likely result and an explanation for his answer. To answer a prediction question the student must state the likely result and explain it in terms of the principle (Yelon, 1989). An example question would be: After a period of fasting (new situation), do you think the level of insulin in blood will be high or low (likely result)? Why (explanation)? To answer this question the student would say that the concentration of insulin will be low (the likely result), and state that this is because after fasting the level of glucose in blood is low, and low glucose levels will not trigger the secretion of insulin from the pancreas (explanation in terms of the principle).

Recall. In a recall question I asked the student to state information mentioned in the instruction. In answering a recall question the student must state information mentioned in instruction. An example question would be: What is the function of insulin? To answer this question the student would say: the function of insulin is to regulate the level of glucose in blood.

2. Analogies have a positive influence on low-ability learners.

Irizarry (1990) concluded that the use of analogies in self-paced instructional booklets significantly improved student achievement. Furthermore, the results suggest that low-verbal-ability students benefited more than those of high verbal ability, and that students perceived the inclusion of analogies in the instructional materials to be interesting and recommended their use.

Bean, Singer, and Cowen (1985) found that using analogical study guides were most effective for those who showed below-average comprehension on previous class tests, and no significant differences for those who have average and above-average comprehension scores.

Wiesenberg (1990) examined the influence of presenting analogical pictures in text to adults learning abstract concepts. Findings indicated that analogical pictures helped more those who were low visual learners.

3. Analogies have a positive effect when there is enough time for students to study the analogies.

Simons (1984) showed that there is a positive effect of including written analogies in text on students' retention and comprehension, but only if students have as much time as they want for reading the material.

Overall, the previous studies demonstrate that including analogies in text has a positive effect on student performance, especially when students have enough time to study the analogy or if they are low-ability students. There is indication that analogies may be helpful more in improving

comprehension questions compared to recall questions, and more helpful in delayed recall than immediate recall.

In this study I used both recall questions and comprehension questions (explanation and prediction questions) to investigate the influence of using analogies on both types of questions. In addition, I used delayed recall because I thought this would more likely show the positive influence of analogies (see the method section for detail).

Analogies' Effectiveness in Instruction

As I mentioned in the introduction, despite the importance of this issue, little research has been conducted to investigate the influence of using analogies in a teaching situation that involves the interaction between a teacher and students. I was able to cite only three studies that dealt directly with this critical issue. The results of these studies are inconclusive. The first study (Gable & Sherwood, 1980) indicates no differences in the performance of students who received analogies compared to control groups. The second study (Dupin & Johsua, 1989) suggested some positive effect. The results of the third study (Clement, 1993) suggest large positive effect. The following is a discussion of these three studies.

Gable and Sherwood (1980) investigated the effect of using analogies over a wide variety of chemistry topics in high school chemistry classrooms for the entire school year on student's achievement. Teachers in the treatment groups presented ten chemical concepts in terms of analogies. In

the control groups additional examples were presented instead of analogies. The students' levels of logical thinking according to Piagetian levels were assessed using a shortened version of the Longeost test.

Results indicated that using analogies in instruction did not increase achievement for all students. Students who scored high on the modified Longeost test, those who reached the formal level of thinking, profited more from additional examples than from analogies. Students who scored lower on the Longeost test, those who still in the concrete level, profited more from analogies. There was no significant difference in favor of the analogy groups compared to the control groups.

Dupin and Johsua (1989) used a train analogy to teach sixth and eighth grade students about electricity. After discussing students' conceptions, the teacher made an experiment to provoke students' dissatisfaction with their current conceptions about electricity. The experiment demonstrated that the current in both sides of the bulb is equal. After that, the teacher presented the analogy and asked students to map the relationships between the elements in the vehicle (train or refrigerator) to the corresponding elements in the target (electricity). Results indicate that sixth grade students were not able to do the mapping process on their own successfully. Eighth grade students, however, were able to do that.

The researchers repeated the experiment with tenth grade students using a refrigerator analogy to teach them about some advanced concepts about electricity. Students in the control and experimental groups answered a questionnaire before and one month after instruction. Results indicate that the experimental group did better than the control group. However, Dupin and Johsua did not indicate if this difference is statistically significant or not.

Also, Dupin and Johsua asserted that neither of the analogies presented alone would achieve the cognitive aims the researchers intended. Thus, they suggested that maybe presenting the two analogies successively as some researchers suggested (e.g., Spiro et al, 1989), because each will deal with different aspect of electricity.

Clement (1993) used bridging analogies and explanatory models to teach students three lessons in mechanics. Lessons were presented in a discussion led by the teacher. Results indicate there are large differences in pre-posttest gains in favor of the experimental group.

The combined results of the above studies (excluding the Clement study, in which a special type of analogy in addition to explanatory models were used) suggest that analogies have a modest value in classroom learning.

I think there is a possibility that the influence of analogies may have been undermined due to the way some of these studies were conducted. In the study where no differences were detected (Gable & Sherwood, 1980) analogies

were used over an extended period of time (an entire school year) to teach whole units that contained a variety of concepts, but only some of them were presented through analogies. This procedure may not be sensitive enough to detect the influence of using analogies on students' learning of a particular concept.

Also, in the Gable and Sherwood study, researchers used multiple choice tests to assess students learning. However, this type of test may undermine the benefits of analogies in two ways:

1. One of the-advantages of using analogies (comprehensive analogies in particular) is that they permit the learning of new concepts "not in bits of information but as integrated parts within an existing organization" (Stepich & Newby, 1988 p.135). Multiple choice tests do not require students to explain the targeted concept as a whole, and thus fail to assess students' understanding of the whole concept.
2. Another advantage of analogies is that they facilitate the retrieval of information about the targeted concept by providing retrieval cues (Stepich & Newby, 1988). Multiple choice tests contain the correct answer and the results depend on the students' ability to recognize the correct answer, not on retrieving it from memory independent of any cue.

What is more important is that in all previous studies the purpose was limited to answer the question: *whether analogies used in instruction helped students to learn*, but

the crucial question of: *how analogies helped to accomplish that?* was not investigated. This study will address this question by qualitatively analyzing what a student is thinking about in preparation to answering questions related to the three categories of questions mentioned above. Students saw a videotape of their answers to the three categories of questions and I asked the students to describe what they were thinking about before answering each question (see the method and measures sections for more details).

There is a great need for more research on the influence of analogies in an instructional setting. Little research has been conducted in this area and with little attention on 'how' analogies influence students' thinking. There is a need for more research that does not limit itself to seeing *whether analogies are effective*, but goes beyond that to investigate *how analogies influence students' learning*. This study is intended to shed more light on both questions.

CHAPTER 2:
OBJECTIVES AND HYPOTHESES

OBJECTIVES

The objective of this study is to answer the following two questions:

1. Does the use of an analogy in instruction help students learn a scientific principle better than instruction without an analogy?
2. How does the use of an analogy in instruction influence students' learning?

In the first question better is assessed by comparing the mean scores of two groups. One group received an analogy as part of instruction and the other did not.

In the second question, students' learning refers to the ability of the students to answer questions I presented to them after instruction (see the method section for a description of the interviews I used in this study).

HYPOTHESES

Hypotheses Related to the First Question:

The first question of this study is focused on *whether* the use of analogies in instruction improves students' learning. The following are the first and second hypotheses that are related to this question, and the rationale behind each hypothesis.

First Hypothesis

Students who receive analogies will have significantly higher total scores on questions after instruction, indicating that the use of analogies improves the learning of the targeted principle.

This hypothesis is based on the literature about the positive influence of analogies on students' recall and comprehension. Stepich and Newby (1988), for example, argued that analogies will improve students' recall of the targeted information. The vehicle part of the analogy will provide cues to recall the equivalent elements in the targeted principle. Gentner and Gentner study (1983) argued that the vehicle part of the analogy will enable students to formulate specific explanations and predictions about the target domain, which improve students' comprehension of the targeted domain. In this study students' learning is assessed by

recall, explanation, and prediction questions. Therefore, I expect that students' who receive analogies will have significantly higher total scores on these questions.

Second Hypothesis

Students who receive analogies will benefit more in explanation and prediction questions, compared to recall questions.

As indicated by Donnelly and McDaniel (1993), including analogies in text was helpful in improving students' answers on inferential questions (which are equivalent to explanation and prediction questions in this study) but it had a negative effect on answering basic level questions (equivalent to recall questions in this study). Donnelly and McDaniel interpreted this by arguing that analogies diverted students' attention away from the details and information in the target concept because students were focusing on the familiar domain of the vehicle.

However, I expect that analogies will improve students' answers on recall questions because in this study the analogy is introduced by a teacher, not through text as in the Donnelly and McDaniel study. Instruction will help students focus on the target principle by emphasizing it through questioning during instruction. Also, as I explained in the literature review, other studies (e.g., Radford, 1989) showed a positive effect on recall question. Therefore, the net result will be an improvement on answering recall questions

but to a lesser degree compared to the improvement in the explanation and prediction questions.

Hypotheses Related to the Second Question:

The second question of this study focused on *how* analogies influence students' learning. The following are the third and fourth hypotheses that are related to this question and the rationale behind each hypothesis:

Third Hypothesis

Analogies will help students to answer recall questions by providing cues that help them remember the targeted principle.

The above hypothesis is based on the arguments made by some authors (e.g., Stepich & Newby, 1988). The vehicle part of the analogy will provide cues to recall the equivalent elements in the targeted principle. According to this hypothesis a student may answer the question: what part of the body is responsible for controlling the body temperature? by first remembering the thermostat in the vehicle part of the analogy, and then mapping it to its equivalent in the target, which is the hypothalamus. I expected this to show in students' answers and comments on the interview questions (see the measures section for details).

Fourth Hypothesis

Analogies will help students answer explanation and prediction questions in two ways. First, they permit the learning of the targeted process as a whole, not as isolated parts of information. Second, students will use the vehicle

part of the analogy to infer some equivalent relationships and predictions in the targeted part of the analogy.

This hypothesis is based on literature regarding analogical reasoning (e.g., Stepich & Newby; Gentner & Gentner, 1983). As I said above the first way by which analogies will improve students' answers in explanation and prediction questions is by allowing the understanding of the concept as a whole (Stepich & Newby).

Regarding the second way, the Gentner and Gentner study (1983) demonstrated that the vehicle part of the analogy will enable students to formulate specific predictions about what will happen in the target process. Again, I expected this to show in students' answers and comments on the interview questions (see the measures section for details).

CHAPTER 3: METHODOLOGY

DESIGN

The objective of this study is to answer the following two questions:

1. Does the use of an analogy in instruction help students learn a scientific principle better than instruction without an analogy?
2. How does the use of an analogy in instruction influence students' learning?

To answer the above questions I used a design to contrast the performance and reasoning of students receiving analogies with those who do not receive analogies. I performed two experiments. The first experiment is the original study in which I taught two lessons (Insulin lesson and Hypothalamus lesson). I did a follow-up second experiment to help explain some of the results I obtained from the first experiment. To do that I taught one lesson (Insulin lesson) in the second experiment with two major changes. I removed the illustrations and assessed students' performance after a longer period of time (see details in the procedure section). I called the lesson in the second experiment the Second Insulin lesson to distinguish it from the Insulin lesson I used in the first experiment.

The following is a description of the design I used in this study:

In the first experiment I formed four groups so that each group contained 8 students. Two groups received tutoring with an analogy about one of the two lessons, the other two groups received tutoring about one of the two lessons but without analogies (Control) (See Table 2). I interviewed all students before and after instruction.

I used the same design in the second experiment, but with 5 students receiving tutoring about the insulin lesson with analogies, and 5 receiving tutoring without analogies (control group).

Table 2

The Distribution of Students Into the Treatment and Control Groups

	Lesson	
Group	Insulin lesson	Hypothalamus lesson
Control group (No Analogy)	8 students	8 students
Treatment group (Analogy)	8 students	8 students

SAMPLE

In the first experiment the sample consisted of 32 undergraduate students (22 females and 10 males) from Kuwait University. In the second experiment the sample consisted of 10 undergraduate students (4 females and 6 males) from Kuwait University. These students were enrolled in courses offered by the College of Education and they represented various specializations (e.g., Education, Biology, and engineering). Students volunteered in this study upon a recommendation by their instructors. I assigned students randomly to the experimental and control groups. I did this by randomly pre-assigning treatments to the numbers representing the total number of students in each lesson (which include the control and the experimental group). For example, in the insulin lesson the number of students is 16. I started by randomly pre-assigning a treatment (Analogy or No Analogy) for each number from 1 to 16, so that there are 8 students representing the Analogy group (experimental group) and 8 students representing the No Analogy group (control group). The numbers from 1 to 16 indicate also the order by which students participated in this study (e.g., number 1 represents the first student volunteered to participate in the insulin lesson). Therefore, each student was

pre-assigned a treatment according to his/her order of participation.

METHOD

First Experiment

I taught students individually about one of the two processes mentioned above (Insulin lesson or Hypothalamus lesson). The instruction that I used has the following characteristics:

1. The instruction is individualized instruction or a tutorial. I taught one lesson to each student individually.
2. The instruction (in both experimental and control groups) is interactive, which means that the student is involved in the learning process. To insure this I did the following: (a) I encouraged each student to feel free to ask questions or make statements about the topic any time during instruction (stated in the directions before instruction); b. I included questions throughout instruction to help the student to: i. recall his previous knowledge about the topic, ii. anticipate the upcoming information, iii. incorporate the lessons' information through explaining (paraphrasing) some parts of the lesson, and iv. think with the teacher by asking him/her to predict what will happen in a given situation.

From a teachers' perspective, these questions helped me to determine if the student understood the information I

presented to him, and if I needed to repeat some parts of the instruction.

3. I used a written protocol as a guideline to deliver instruction and to insure that each student received complete information about the topic (see Appendices A, B, for the Insulin and Hypothalamus lessons protocols). The written protocol also helped to deal with my biases as a researcher, because the protocol insured that every student received the information necessary to answer the questions in the interview after instruction, and that all students were taught in a similar or standard way. In addition, the introductory part of the written protocol helped all students to understand what to expect as participants in this study.

Since many students who participated in this study came from the same class, there was the possibility of students talking to each other and influence the validity of students scores by introducing order effect (students who participate later do better because they get more information about the topic from other students). Therefore, at the end of instruction I instruct students not to talk to other students about the experiment before I finish the experiment procedures with all students. I examined students scores and there was no indication of order effect.

I evaluated each student's knowledge and understanding of the targeted principle before and after instruction. I did that by interviewing students individually before and after instruction. I followed an interview protocol that was

the same for all students (interview protocols are part of the lesson protocols provided in Appendices A and B). I tape-recorded all interviews. I video-taped the interviews after instruction only. I used the videotape in the double stimulus procedure explained later in this section. The interview before instruction was directly before instruction. On the other hand, the interview after instruction occurred two days later. As I indicated in the literature review section, the results of previous studies (Radford, 1989; Simons, 1984, although inconclusive, yet suggest that Analogies are more helpful in delayed recall compared to immediate recall. Radford (1989) found that analogies are more useful in improving delayed recall. In contrast, Simons (1984) found that analogies are more helpful in immediate recall. But the results of other studies (Donnelly and McDaniel, 1993; Gilbert, 1989) in which students' performance was assessed directly after instruction (immediate recall) and no significant differences were found, suggest that analogies are more useful in improving delayed recall.

In this study I delayed the questions for two days because:

1. This encouraged each student to think more before answering each question instead of relying on remembering what s/he just heard if the questions were directly after instruction.

2. Encouraging students to think more before answering helped to examine students thinking using the double stimulus response.

3. Although the evidence is inconclusive regarding the delayed versus immediate recall (as I explained above), based on the arguments which I made in the hypothesis section, I expected that delaying the questions for two days would show more clearly the positive role of analogies in helping students to recall, explain, and predict certain aspects of the targeted principle.

I instructed all students to follow these steps in answering all interview questions (in both before and after instruction interviews):

1. Hear the question and make sure that you understand the question (if necessary, I will repeat the question to help students understand the question).
2. Take as much time as necessary to think and prepare the answer.
3. Tell me if you are ready to answer.
4. Answer the question.

I used the double stimulus procedure only in the interviews after instruction. The students saw the video of the interview and I asked them about what they were thinking about before answering each question. I tape-recorded their responses.

Second experiment

The purpose of the second experiment was to explain some of the results related to the first experiment. I wanted to know if removing the illustrations from instruction and assessing students' performance after a longer period would increase the effectiveness of the analogies. I also wanted to know why many students mentioned the analogy in the first question, which happened to be a recall-type question.

To answer the above questions, I used the same procedure mentioned above to individually teach students in the experimental and control groups about the Insulin lesson, but with two major differences. First, I removed all the figures I used in the first experiment. Second, I waited for one week to interview students after instruction, compared to two days in the first experiment. I did this to see if these new conditions would increase the effectiveness of the analogy (See Appendix C for the Second Insulin lesson protocol)

A third difference is related to the ordering of questions in the interview after instruction. In the first experiment I started the interview after instruction with a recall type question. In the second experiment I moved the recall question to be the third question, and started by an explanation question. I did this because in the first experiment most students mentioned the analogy in the first question. I wanted to see if the inclination of students to mention the analogy in the first question is related to the

order of the question (being the first question) or the type and nature of the question (being a recall general question).

MEASURES

Since the interviews are in Arabic, I translated and transcribed all the interviews (before and after instruction). To determine the accuracy of my translation I provided a graduate student, who is fluent in both English and Arabic, with the Arabic transcripts of 2 students and asked him to translate it to English. I compared my translation with his translation. There were differences related to word choice, but the overall meaning was similar.

After conducting the experiment with all students, I asked an individual to assign a number to each student, so that I did not know the students' name as I correct his or her answers. This reduced the probability of scoring bias.

I scored the questions before and after instruction. I used model answers to score students' answers (See Appendices D and E for the model answers of Insulin And Hypothalamus lessons). For the explanation and prediction questions each question was worth 3 points. For the recall questions, the general recall question (asking the student to explain the targeted principle in as much detail possible) was worth 5 points, and the remaining 2 questions were worth 2 points each. The reason behind assigning more points to the first question is because it required students to recall most of

the information or the whole picture about the targeted principle. Unlike the rest two questions (which I assigned 2 points) involved recalling specific and small facts. Using the insulin lesson as an example, the total score of the 9 questions for the interview after instruction is 27 points ([3 x 6] + 5 + 2 + 2). I prepared a model answer for each question and used it to judge the correctness of students' answers. A student may get a (0) grade if his answer is completely wrong, and may get (1.5) if he gets half of the answer right. To be fair to all students, I used a two-step process in correcting the answers. First, I read all students' answers to each question without assigning a grade. Then I read them again to assign grades.

To get interrater reliability, I trained a graduate student to score the questions, and asked him to score the questions of 6 students that I had chosen randomly from all students who participated in this study. I correlated his scores with my scores for the 6 students and got r = 0.88.

I used the scores for the questions before instruction to assess each student's prior knowledge regarding the targeted principle. A student who knew too much about the targeted principle was not considered, and was replaced by the following student. I considered a student to know too much if he or she was able to answer more than 3 questions (out of 6 questions) in the interview before instruction. This happened one time only in the insulin lesson. The

student was able to answer four questions (out of 6), therefore, I replaced the student.

The questions in the interview after instruction assessed the influence of analogies on students':

1. Ability to recall factual knowledge about the targeted principle.
2. Ability to explain the targeted principle.
3. Ability to predict new situations related to the targeted principle.

ANALYSIS

To test the first hypothesis (students who receive analogies will learn more about the targeted principle than those who do not receive analogies) I used a t-test (n=8) to compare the mean score of the group who received analogies with the mean score of the control group. Since I have two lessons, I performed two t-tests. I also combined the scores of two groups who received analogies, and combined the scores of the two control groups. I used a t-test (n=16) to compare the mean scores of the resulting two groups.

To test the second hypothesis (students who receive analogies will benefit more in explanation and prediction, compared to recall questions) I compared the average score of each question type for the groups that received analogies with the average score of each question type for the control groups. For example, I calculated the means for recall, explanation, and prediction questions for the two groups that received analogies and compared it to the mean for factual knowledge, explanation, and prediction questions for the control groups.

To test the third hypothesis (analogies will help students answer factual knowledge questions by providing cues that help to remember the targeted principles) I showed each

student the video of his/her interview after instruction. I stopped the video just before the student answered each question, and asked him/her about what he/she was thinking about. I also stopped the video after each question and asked if the students could add more information regarding what they were thinking about before answering the question. My prediction was that students would think about the analogy and use it to retrieve information regarding the targeted principle, and this would show in their description of their thinking processes as they prepared to answer recall questions.

To test the fourth hypothesis (analogies will help students to answer explanation and prediction questions in two ways, first by permitting the learning of the targeted process as a whole, not as isolated parts of information. Second, students will use the vehicle part of the analogy to infer some equivalent relationships and predictions in the targeted part of the analogy). Regarding the first way I expected this to show as improved ability of students who received analogies to answer explanation questions and prediction questions. Also, I expected that students who received analogies would mention the vehicle part of the analogy (e.g., "emigration" in the insulin lesson) as they described their thinking before answering the explanation and prediction question of the interview after instruction.

In addition, I asked the students who received analogies the following general question at the end of the interview

after instruction (this question is related to the insulin lesson): In answering the previous questions did you think about the emigration situation we talked about two days ago? When did you think about it? This question showed if the student ever thought about the analogy, since the student may have thought about it without mentioning it in his/her description of his thinking. If the student said that he/she never thought about the analogy, this would indicate that the student did not use the analogy to answer the questions of the interview after instruction. This question was not scored since it did not measure student learning about the topic, and because I asked it only to the students who received analogies only.

I used the same previous measures in the second experiment.

CHAPTER 4: RESULTS

I organized this section according to the two questions of this study and the relevant hypotheses. I will start with the results related to the first question, which includes the first and second hypotheses. I will report the relevant results related to the first experiment, which include two lessons: the insulin lesson, the hypothalamus lesson, and the two lessons combined. Then I will report the results of the second experiment, which includes the second insulin lesson. This lesson is different from the insulin lesson of the first experiment in that it does not include illustrations, and has a period of one week between instruction and the interview instead of two days as in the insulin lesson of the first experiment.

After that, I will report the results relevant to the second question, which includes the third and fourth hypotheses of this study. Similar to the first question, I will start with the first experiment and then the second experiment.

In Appendix F I listed tables of each students' scores on each question. The tables are organized according to lesson (Insulin lesson, Hypothalamus lesson, or second Insulin lesson) and treatment (Analogy or No analogy). I also

listed tables of students' scores on each question according to the type of question (recall, explanation, or prediction). The means, and the standard deviations are indicated.

Question I

Does the use of an analogy in instruction help students to learn a scientific principle better than instruction without an analogy?

First Hypothesis

The first hypothesis of this study (which is related to the first question mentioned above) states that students who receive analogies will learn more about the targeted principle than those who do not receive analogies. Learning is assessed by the ability of the students in each group to answer the questions of the interview after instruction. The following are the results of the first experiment and the second experiment that are relevant to this hypothesis.

First Experiment

insulin lesson.

Figure 1 compares the means of the Analogy and No Analogy groups for the Insulin lesson, the Hypothalamus lesson, the two lessons of the first experiment combined, and the second Insulin lesson of the second experiment.

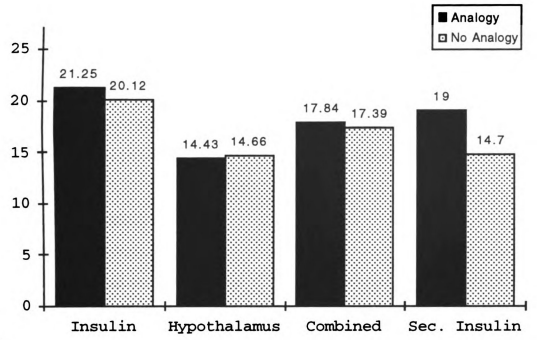

Figure 1. The Mean Scores of the Analogy and No Analogy Groups for the First and Second Experiment

The mean for the Insulin Analogy group is 21.25. The mean for the Insulin No Analogy group is 20.125. I performed a two sample t-test (n=8). The result shows that there is no significant statistical difference between the two groups $p > 0.05$ ($p = 0.58$).

hypothalamus lesson.

Figure 1 indicates that the mean for the Hypothalamus Analogy group is 14.4. The mean for the Hypothalamus No Analogy group is 14.6. I performed a two sample t-test (n=8). The result shows that there is no significant statistical difference between the two groups $p > 0.05$ ($p = 0.91$).

the two lessons combined.

Figure 1 shows that the mean for the Insulin and Hypothalamus Analogy group is 17.84. The mean for the Insulin and Hypothalamus No Analogy group is 17.39. I performed a two-sample t-test (n=16). The result shows that there is no significant statistical difference between the two groups $p > 0.05$ ($p = 0.81$).

Second Experiment

second insulin lesson.

As indicated by Figure 1, the mean for the Insulin Analogy group is 19. The mean for the Hypothalamus No Analogy group is 14.7. I performed a two sample t-test (n=5). The result shows that there is no significant statistical difference between the two groups, $p > 0.05$ ($p = 0.12$).

The results of the first experiment, which includes the Insulin and Hypothalamus lessons, indicate that analogies did not help students learn more than students who did not receive analogies. The result of the second experiment which included the insulin lesson without illustrations and with more time between instruction and interview, is also statistically not significant. However, the p value of this experiment ($p = 0.12$) is much smaller compared to the p value of the insulin lesson in the first experiment ($p = 0.58$). Thus, although the difference was statistically not significant in the second experiment, comparing the p values of the first and the second experiments indicates that the

emigration analogy in the insulin lesson helped students learn more in comparison to the No Analogy group, after removing the illustrations and testing students after a longer period of time (one week vs. two days).

Second Hypothesis

The second hypothesis of this study is related to the first question of this study; Does the use of an analogy in instruction help students to learn a scientific principle better than instruction without an analogy? The second hypothesis states that students who receive analogies will benefit more in explanation and prediction, compared to factual knowledge questions. To test this hypothesis I compared the average score of each question type for the groups that received analogies with the average score of each question type for the control groups.

First Experiment

insulin lesson.

Figure 2 compares the mean scores of Insulin Analogy and No Analogy groups according to the three types of questions in the interview after instruction. The three types of questions are recall, explanation, and prediction. Each type of question is represented by three questions in the interview, with a total score of 9.

The mean of the Analogy group on recall questions is 7.3, compared to the mean of the No Analogy group which is 6.1. The mean of the Analogy group on explanation questions is 7.1, compared to the mean of the No Analogy group which is 7.2 . The mean of the Analogy group on prediction questions is 6.7, compared to the mean of the No Analogy group which is 6.7. I performed a t-test to see if there was any

significant difference between the means of each question type. None of these differences were significant $p > 0.05$.

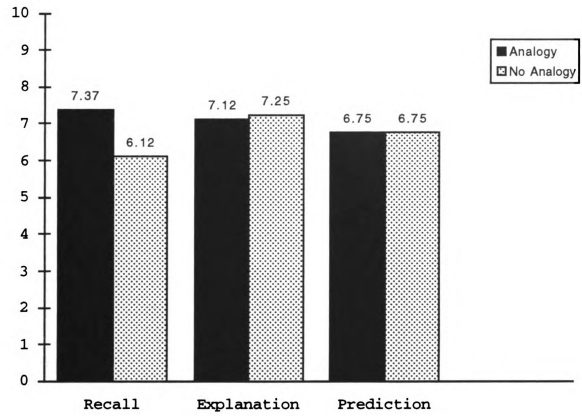

Figure 2. A Comparison Between the Score Means of the Insulin Analogy and No Analogy Groups on the Three Types of Questions

hypothalamus lesson.

Figure 3 compares the mean scores of Hypothalamus Analogy and No Analogy groups according to the three types of questions in the interview after instruction. The mean of the Analogy group on recall questions is 5.8 compared to 6.23 the mean of the No Analogy group. The mean of the Analogy group on explanation questions is 4.18, compared to the mean

of the No Analogy group which is 3.68. The mean of the Analogy group on prediction questions is 5.5, compared to the mean of the No Analogy group which is 5.4. None of these differences were significant $p > 0.05$.

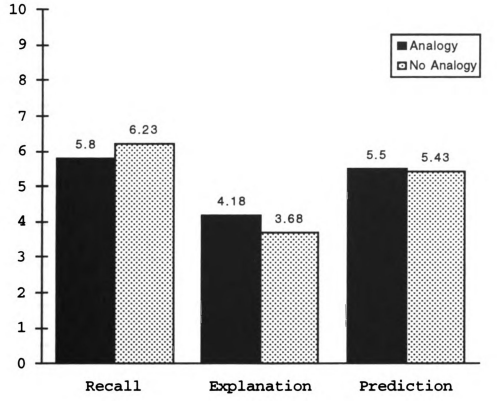

Figure 3. A Comparison Between the Score Means of the Hypothalamus Analogy and No Analogy Groups on the Three Types of Questions

the two lessons combined.

Figure 4 compares the mean scores of the combined (Insulin and Hypothalamus) Analogy and No Analogy groups according to the three types of questions. The mean of the combined Analogy group on recall questions is 6.5, compared

to the mean of the combined No Analogy group which is 6.1. The mean of the combined Analogy group on explanation questions is 5.6, compared to the mean of the No Analogy group which is 5.4. The mean of the Analogy group on prediction questions is 6.1, compared to the mean of the No Analogy group which is 5.4. None of these differences were significant $p > 0.05$.

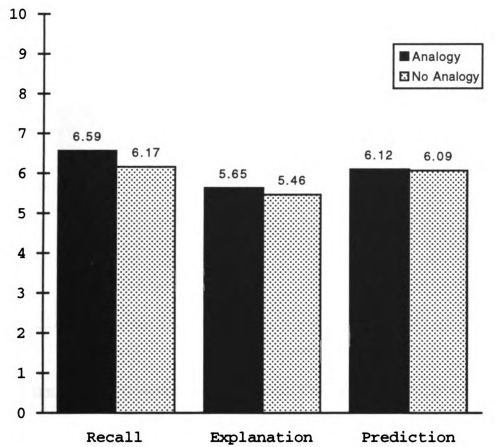

Figure 4. A comparison Between the Score Means of the Combined Insulin and Hypothalamus Analogy and No Analogy Groups on the Three Types of Questions

Second Experiment

second insulin lesson.

Figure 5 compares the mean scores of Insulin Analogy and No Analogy groups according to the three types of questions in the interview after Instruction.

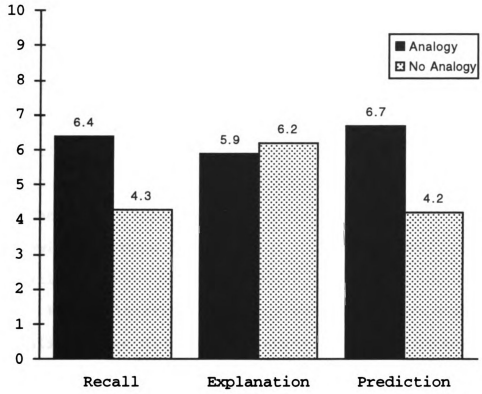

Figure 5. A Comparison Between the Score Means of the Insulin Analogy and No Analogy Groups on the Three Types of Questions, the Second Experiment

The mean of the Analogy group on recall questions is 6.4, compared to the mean of the No Analogy group which is 4.3. The mean of the Analogy group on explanation questions

is 5.9, compared to the mean of the No Analogy group which is 6.2. The mean of the Analogy group on prediction questions is 6.7, compared to the mean of the No Analogy group which is 4.2.

I performed a t-test (n=5) to see if any of these differences is statistically significant. Only the difference between the two means of the recall questions is statistically significant $p < .05$ ($p = 0.041$).

These results indicate that the emigration analogy in the Insulin lesson was most useful in helping students to recall information. The difference between the means of the recall questions is 1.2 points in favor of the analogy group. This benefit reached a significant level ($p = 0.041$) in the second experiment after removing the drawings and allowing for more time between instruction and interview questions.

For explanation questions the emigration analogy in the insulin lesson did not help students answer these questions. This is true for the first and second experiment. In fact, in both experiments the mean of the No Analogy group was slightly higher than the mean of the Analogy group.

Regarding prediction questions, the means of the Analogy and No Analogy groups were identical = 6.75. This means that the emigration analogy did not help students learn more under the circumstances of the first experiment. However, in the second experiment in which I removed the illustrations and allowed for more time between instruction and interview

questions, the difference between the two means is 2.5 points in favor of the analogy group.

In the Hypothalamus lesson, the thermostat analogy did not help students to answer recall questions. To the contrary, there is a 1/2-point difference in favor of the No Analogy group. Thus there is an indication that the thermostat analogy may have hindered students recall. Regarding explanation questions, the thermostat analogy slightly helped students answer this type of question since there is a 1/2-point difference in favor of the analogy group.

For prediction questions, the means of the Analogy group and the No Analogy group are almost the same. This indicates that the thermostat analogy, under the conditions of the first experiment, did not help students answer this type of questions better than the No Analogy group.

Question II

How does the use of an analogy in instruction influence students' learning?

Third Hypothesis

The third hypothesis of this study (which is related to the second question mentioned above) states that analogies will help students answer recall questions by providing cues that help them remember the targeted principles. I predicted that students would think about the analogy and use it to retrieve information regarding the targeted principle, and this would show in the students' answers to the interview questions or their descriptions of their thinking process as they prepared to answer recall questions.

Table 3 lists the lessons and the number of students who mentioned the analogy and the number of students who did not mention the analogy.

Table 3

The Number of Students who Mentioned the Analogy and Those Who Did Not Mention the Analogy in Each Lesson

Lesson	Mentioned Analogy	Did not Mention
Insulin	3	5
Hypothalamus	4	4
Second Insulin	2	3

I considered mentioning any word related to the vehicle part of the analogy (e.g., emigration situation in the insulin lesson), either in the students' answers to the interview questions and/or in the students' comments on the videotaped interview, to be the criteria for considering a student as one that mentioned the analogy.

Table 4 is a list of the names (not the real names) of all students who mentioned the analogy, their gender, group or lesson, where they mentioned the analogy (in their answer and/or comments), and score on the interview after instruction.

Table 4

A List of All Students Who Mentioned the Analogy, their Gender, Group, Where they Mentioned the Analogy (in their Answer or Comments), and Score.

Student Name and number	Gender	Lesson	Answer of	Comments on	Total score
#9 Jacob	Male	Insulin		Q.1 Recall Q.5 Explan	22
#5 Sarah	Female	Insulin		Q.1 Recall	11
#17 Jasmine	Female	Insulin		Q.1 Recall	25
#25 Adam	Male	Hypothalamus	Q.1 Recall Q.9 Explan	Q.1 Recall	17.3
#18 Abraham	Male	Hypothalamus	Q.4 Recall		11.8
#22 Mona	Female	Hypothalamus		Q.1 Recall	19.6
#8 Fatimah	Female	Hypothalamus	Q.6 Predic	Q.6 Predic	12.5
#9 Kareem	Male	Sec. Insulin	Q.1 Recall	Q.1 Recall Q.9 Predic	23
#1 Mohammed	Male	Sec. Insulin	Q.1 Recall	Q.1 Recall	16

Figure 6 is a histogram of the number of students who mentioned the analogy according to the type of question. This indicates where students mentioned the analogy according to question type. For example, in the Insulin lesson there are 3 students who mentioned the analogy in recall type questions and 1 mentioned the analogy in explanation type questions.

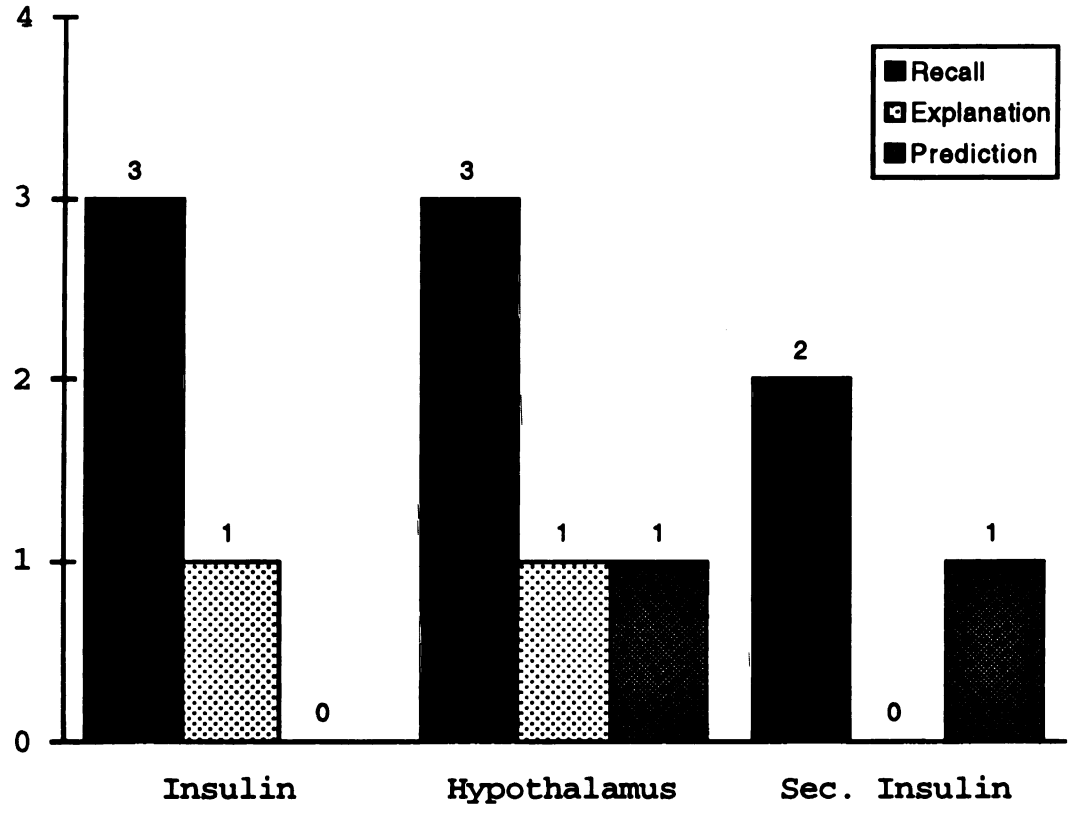

Figure 6. The Number of Students Who Mentioned the Analogy According to Question Type

First Experiment

insulin lesson.

As shown in Tables 3 and 4, out of the 8 students who received the emigration analogy, 3 students mentioned the emigration analogy in their comments on their answers.

All 3 students mentioned the analogy in their comments on the first question, which is a recall-type question. Only 1 student mentioned the analogy in his comments on the fifth question, which was an explanation question.

Students' comments about the first question indicate that they remembered the emigration situation, the vehicle, and used it to construct their answers about the insulin situation, the target. The following are the transcripts of what the students answered when I asked them to comment on their videotaped answers. These are the comments of Jacob on his videotaped interview regarding what went through his mind before answering the first question. In the first question I asked Jacob to use his own words to explain to me how the human body regulates the level of sugar in blood (I identified myself as the Teacher in all transcripts):

> *Teacher: What went in your mind when I asked you this question?*
>
> *Jacob: When you asked the question ... I remembered that we compared insulin hormone and glucose ... we compared it to the emigration administration or the airport.*

Teacher: OK.

Jacob: I remembered the airport and the emigration ... what will happen if one counter is working or two or three ... and I move it with insulin ... insulin hormone.

Jacob explained that he remembered the comparison between the vehicle part of the analogy, the emigration administration, and the target, the insulin situation. He explained that he remembered first what happened in the emigration when one counter is working compared to two or three counters and used this to recall what happened in the human body: "and I move it with insulin ... insulin hormone". This supports the hypothesis that students will use the emigration situation (vehicle) to provide cues which will help them to remember information about the insulin situation (target).

It is important to remember that Jacob did not mention the emigration situation in his correct answer to the question, but that it is in his description of what went through his mind. This means that methods that rely only on students' verbal or written responses will not detect that students actually remembered and used the analogy, as this student did in this example.

These are the comments of Sarah on her videotaped answer to the same first question (how does the human body regulates the level of sugar in blood?):

Teacher: See your answer and tell what did you think about as you answered ... what went in your mind?

The student saw part of her answer.

Teacher: What did you remember here?

Sarah: The paper ... the two papers ... the travelers and so on.

Teacher: OK.

Sarah: I started collecting from here and from here ... and said maybe ... I said what was there.

The student saw the rest of her answer.

Teacher: As you were answering ... what went in your mind?

Sarah: From the paper ... I was recalling.

Teacher: How?

Sarah: I was recalling the drawing ... when you said explain from one ... and go to the second paper about the travelers ... same thing ... from one point to other point.

In this case, Sarah remembered the two drawings of the emigration and insulin and she compared the two situations "from one point to another point" in the process of answering the question. Sarah did this comparison as part of the instruction provided two days before this interview. At the end of instruction and after presenting the analogy to the students, I asked them to use the two figures representing the insulin and emigration analogy to explain how the human

body regulates the level of sugar. So Sarah remembered the comparison she did in the instruction in which she compared each stage in the insulin situation with its equivalent in the emigration situation. For example, she compared the situation before insulin secretion with the emigration area before the arrival of the administrators (see the protocol of the Insulin lesson for the Analogy group in the method section). This point-to-point comparison may have facilitated the recall of how insulin regulated the level of glucose in the blood in a way that is similar to what Jacob articulated earlier. That is, they recalled first what happened in the emigration situation and used this as a cue to remember what happened in the insulin situation.

Jasmine is the third and last student who mentioned the analogy in her comments (on her videotaped interview) regarding what she thought about before answering the first question. The following are Jasmine's comments:

Teacher: What happened?

Jasmine: I was remembering when ... you told me ... the pancreas ... when you told me that sense that there is an increase in glucose in the blood ... so it stimulates it ... and secretes pan ... the ... insulin ... what else ... yes the insulin ... when you showed me the picture ..

Teacher: Which picture?

Jasmine: Which contained the transporters after ... they come ... I remembered the airport.

Teacher: How did this help you?

Jasmine: That at first they were not active and then how they became active ... when the administrators came ... at first there were crowds which mean excess in glucose ... after that .. the employees were sitting ... than the administrators came like ... when pancreas saw that ... so it secretes the insulin ... the inactive became active ... and the crowds decreased.

Here Jasmine said that she remembered the figure that illustrated the influence of insulin. This seemed to remind her that she recalled the airport situation as she thought about this question. I think my next question to her, "how this helped you?" was a leading question. A better question would be "can you elaborate more?" or something to that effect. Nevertheless, Jasmine's description of how the emigration situation helped her shows that she benefited from the emigration situation by recalling and understanding how the transporters became active:

Teacher: How did this help you?

Jasmine: That at first they were not active and then how they became active ...

This is at the heart of the process that explain how insulin regulates the level of sugar in the blood. I think the ability to recall and understand this central and crucial point helped the student remember the other details of the targeted principle. In addition, in her description the

student went back and forth between the emigration situation (vehicle) and the insulin situations (target), mapping *correctly* between what happens in the two situations. This correct mapping between the two situations may have also facilitated the recall of what happened in the insulin situation in a way that is similar to what the previous two students did. That is, they used the emigration situation as a cue to recall the insulin situation.

hypothalamus lesson.

As indicated by Tables 3 and 4, 4 students out of 8 mentioned the thermostat. Out of these 4 students, 3 students mentioned the thermostat in two recall-type questions involving the first question (2 students) and the 4 question (1 student).

In the first question I asked students to explain to me how the human body maintains a stable body temperature through the sweat glands. As in the insulin lesson, students' answers and comments indicate that the students remembered the comparison between the hypothalamus and the thermostat and used the thermostat as a vehicle to remember how the hypothalamus regulates the body temperature. This is what Mona said in her comments regarding what she thought about before answering the first question (how does the human body maintain a stable body temperature through the sweat glands?):

Teacher: What went in your mind regarding the first question?

Mona: I was remembering the table ... the one you shown me about the hypothalamus ... and the one about the air conditioning ... so that's why I was answering ...from it ... I did not remember exactly what we said.

Mona explained that she remembered the drawings about the thermostat and the hypothalamus, and used these two drawings to construct her answer. Mona indicated that she did not remember exactly what we said about the two drawings, but she was able to construct her answer by remembering the drawings of the thermostat and the hypothalamus, the two parts of the analogy.

Adam mentioned the thermostat in his comments and also in his answer to the first question. This is part of his answer to the question, "how does the human body maintain a stable body temperature through the sweat glands?":

Adam: We will first go with increasing the secretion ... first thing his body temperature will be high ... this will cause an increase in the blood temperature ... the blood will go to the brain it will reach the ... thallamus ...

Teacher: OK.

Adam: OK ... this thalamus is considered like a thermostat ... OK ... it increases and decreases ... the ... sweat ... it is the control center of

sweat in the whole human body ... OK ... so when the temperature increases it will order all the sweat glands in the body to secretes sweat ... when it secret sweat the temperature will decrease ... and return ... do you want the decrease condition?

This is part of Adam's comments describing what he thought about before stating his previous answer (mentioned above):

Teacher: OK ... what went in your mind after you heard this question?

Adam: The air conditioner ...

Teacher: Mmhmm.

Adam: And the human body .. the two maps.

In his answer Adam mentioned the thermostat when he wanted to talk about how the hypothalamus increases the secretion of the sweat glands. He said, "this thalamus (hypothalamus) is considered like a thermostat" it is the "control center of sweat in the whole human body". This shows that the Adam recalled the air conditioning situation, which is confirmed by his comments on his videotaped answer when he said that he remembered "the air condition" and "the human body .. the two maps (figures)" of the air conditioner and the human body. This implies that Adam used the two figures in constructing his answer. Adam's comments do not indicate how he utilized the figures of the two situations to answer the question.

Abraham mentioned the analogy in question four. Question four is a simple recall question asking the student to name the organ that controls the temperature of the human body. The answers indicate that Abraham resorted to the analogy when he had difficulty remembering the name of the organ (the hypothalamus).

> *Teacher: What is the name of the part or organ in the human body that controls the temperature of the human body?*
>
> *Abraham: The theo .. theo .. the theo .. we talked about it .. the theo .. the blood passes through it .. we said it is like the thermostat of the .. theo .. theomalus or something .. approximately .. I do not memorize it well.*

Abraham mentioned the thermostat to indicate that he knew the organ, but could not remember its name. This shows that Abraham recalled the air conditioning analogy, and the thermostat. Then he tried to use the thermostat in the air conditioning situation to remember its equivalent in the human body, which is the hypothalamus. This again supports the hypothesis that students will use the elements in the vehicle (thermostat) to provide cues that help them remember their equivalents in the target (hypothalamus).

Second Experiment

second insulin lesson.

As indicated by Table 3 and 4, 2 students out of 5 students mentioned the analogy in their answers and comments.

Similar to the students in the insulin lesson of the first experiment, both students mentioned the analogy on the first question. It is important to remember that I changed the *position* of this question from the first question to be the third in this experiment (I referred to it as the first recall question to avoid confusion). I did this to see if the position of this question influenced student recall of the analogy. Yet, similar to the first experiment, all students recalled the emigration analogy in the first recall question that required them to provide or recall the whole picture about the insulin situation. Add to this the fact that in the Hypothalamus lesson 2 out of 3 students also mentioned the analogy in the first recall question (similar general recall question). This implies that analogies were used more in recall questions that required students to give the big picture about the targeted domain, in contrast to recall questions that focused on a specific detail (for example, recalling the name of the organ that controls the body temperature).

Both students in the second insulin lesson mentioned the analogy after I asked them to explain to me or provide more details regarding what they had already said about the targeted principle. That is, students mentioned the airport (vehicle), in the process of explaining to me how insulin regulates glucose in the body (target).

The following is the answer of Kareem on the first recall question:

Teacher: Using your own words, and with as much detail possible, explain to me how the human body regulates the level of sugar in blood. (Repeating the question)

Kareem: When there is a shortage of glucose in the blood ... the pancreas gland starts the secretion of insulin ... insulin regulates glucose in the blood through increasing glucose transporters in the cell membrane ...

Teacher: Explain this to me.

Kareem: It regulates glucose in the blood like the airport.

In his answer Kareem mentioned the analogy to explain to me how insulin regulates the level of glucose in the blood. However, Kareem did not elaborate on the analogy; he only said "It regulates glucose in the blood like the airport". This may be because he thought there was no need to elaborate, since I was the one who provided the analogy in the first place, or simply because I did not ask him to elaborate on what he said. In addition, Kareem provided short answers to all other interview questions.

Nevertheless, mentioning the analogy indicates that Kareem thought about the emigration situation as he tried to answer the question. This is confirmed by his comments after he saw the video depicting him thinking before answering the question. So here he is describing what went through his

mind before answering the first recall question (how does the human body maintain a stable temperature?):

Teacher: What went in your mind?

Kareem: I remembered last Wednesday ... I was recalling the airplane and the airport.

Teacher: You thought about it?

Kareem: Yes I thought about it.

Kareem indicated that he recalled the emigration situation and thought about it when I asked him the question.

The other student who remembered the analogy in the first recall question was Mohammed. This student also mentioned the analogy when I asked him to provide more details for his answer. The transcript shows that Mohammed mentioned the analogy to boost his short and incomplete answer on the question about how the human body regulates a stable body temperature:

Teacher: How do transporters decrease the level of sugar?

Mohammed: It will attach itself to the wall ... attach itself to the cell wall ... this is what I know.

Teacher: Do you have more details?

Mohammed: You gave me an example ... you made an analogy with the airport ... the Kuwait airport when travelers come and they found only one on the counter ... a lot of passengers will be standing in lines in front of that counter ... so in this

situation there will a pressure on that employee ... other employees are talking or something else ... if someone went to the official ... he will organize this process ... so that he distributes other employees on the other counters so that travelers will go to the other counters ... this way the problem will be solved ... everybody will take his luggage and leave ... you made this analogous to the human body ... that the travelers are the glucose ... and the employee is the insulin ... I think I am confused ... I hope I got it right.

Mohammed's answer shows that he was able to recall the emigration situation with good detail. However he did not provide any details regarding the targeted principle, which is how insulin regulated glucose level. In addition, *Mohammed* was not able to map all the elements on the emigration situation (vehicle) to their correct correspondents on the insulin situation (target). Although he correctly mapped the travelers to glucose, he incorrectly mapped insulin to the employees, and did not mention other elements.

Mohammed's comments on his interview video show that he recalled the emigration situation:

T: What went in your mind here?

S: Here .. I remembered every thing .. you tied the situation with examples .. specifically the example of the airport ..

Although I consider mentioning the analogy as a sign that the student is using the analogy in some way to construct his answer. Yet, recalling the analogy does not mean that the analogy is always helping the student in his answer. In this case the student did not map correctly the elements between the two situations and this may have decreased the effectiveness of using the vehicle to recall the target situation.

Fourth Hypothesis

The fourth hypothesis is related to the second question of this study; How does the use of an analogy in instruction influence students' learning? The fourth hypothesis states that analogies will help students to answer explanation and prediction questions in two ways. First, they permit the learning of the targeted process as a whole, not as isolated parts of information. Second, they will use the vehicle part of the analogy to infer some equivalent relationships and predictions in the targeted part of the analogy. I proposed that this would show in the improved ability of students who received analogies to answer explanation questions and prediction questions. This was not confirmed, as I explained in discussing the second hypothesis.

Also, I suggested that students who received analogies would mention the vehicle part of the analogy (e.g., "emigration" in the insulin lesson) as they described their thinking before answering the explanation and prediction question of the interview after instruction. Figure 6 shows that only 4 students out the of the 21 students who received analogies in this study mentioned the analogy in their answers or comments to an explanation or prediction question. This demonstrates that most students were not inclined to recall the analogy and use it to answer explanation and prediction question. Instead they may have focused on the targeted principle and the information directly related to

it. The following is an analysis of the transcripts of the 4 students, starting with the first experiment.

First Experiment

insulin lesson.

Out of the 8 students who received the emigration analogy in the insulin lesson, Sarah was the only student who mentioned the analogy. This happened as she was commenting on the explanation question number 5 (when an individual has a high glucose level in his blood, we say that he has diabetes. What do you think goes wrong in the human body to cause this disease?). Sarah's answer was "the pancreas .. the pancreas gland ... weakness ... in producing the insulin hormone" which is a correct answer. These are her comments on what she thought about before she answered the question:

> *Teacher: What happened here?*
>
> *Sarah: I remembered the same thing ... the story of administrators and the emigration ... I remembered through ... if it increases ... the level of sugar there must be something to reduce it ... if did not let something reduce it ... the people will ... you will get a disease ... similarly in the emigration if you put or increased a new counter ... the number of people in the emigration area ... their number will be large ... unreasonable I mean ... it is difficult for one person to finish their papers in the speed required.*

Sarah said that she remembered the emigration situation when she answered this question. Sarah's description of her thinking process indicates that she started with the situation presented in the question (high glucose level) and applied the same situation to the emigration situation to find the solution. Sarah stated that when the sugar level is high "there must be something to reduce it". She then went to the emigration situation to apply the situation. She said that "similarly" if you want to overcome the same situation in the emigration situation "you put or increased a new counter ..." because if you don not increase a new counter "the number of people in the emigration area ... their number will be unreasonable I mean .. it is difficult for one person to finish their papers ..." This is the situation presented in the question, but it is now in terms of the emigration situation.

Sarah's correct answer implied that she then concluded that the equivalent of not having a new counter in the insulin situation is a shortage in insulin secretion, which is the answer provided by the student. This again supports the hypothesis that students use the vehicle part of the analogy to infer the equivalent predictions in the target part of the analogy, and that this will facilitate answering prediction questions.

hypothalamus lesson.

Out of the 8 students who received the thermostat analogy, 1 student mentioned the analogy in an explanation question, and another mentioned it in a prediction question.

Adam mentioned the thermostat in his answer to the explanation question number 9:

> *Teacher: Let's say that an individual has an accident which resulted in removing a portion of his brain. After the operation this individual experienced a disorder in sweat secretion. Why do you think this happened?*
> *Adam: I think this ... the thalamus ... the thermostat of the body ... it apparently went away or ... something happened to it.*
> *Teacher: And this caused?*
> *Adam: A disorder.*

As I predicted in the measures section, Adam mentioned the vehicle part of the analogy as he answered this question. In his answer, Adam said that the hypothalamus is "the thermostat of the body." Using this metaphor indicates that Adam recalled the analogy between the body and the air conditioning and he mapped the hypothalamus in the body to its equivalent in the air conditioner, which is the thermostat.

Also, Adam's statement shows that the air conditioner reinforced his understanding of the notion that the

hypothalamus is the device that controls the temperature in the body. All this supports the hypothesis that students use the relationships in the vehicle part of the analogy to infer the same relationships in the target domain, and that this would facilitate answering explanation questions.

Fatimah mentioned the analogy in her answer and comments on the prediction question number 6. In her answer she started by indicating that there will be changes in the body because of the new situation presented in the question. Although this is a correct start, Fatimah was not able to go beyond this to explain what the changes are, and why they happen. After I asked Fatimah twice to explain to me further, she mentioned the analogy. This is the transcript of the question and what she said in her answer:

> ***Teacher: We know that the normal temperature of the human body is thirty seven, it is called the set point. Let's say that an individual took certain medicine that suddenly changed the set point from thirty seven to thirty eight or ninety eight, what do you think is the reaction of the human body in this case?***
>
> ***Fatimah: The body will change ...***
>
> ***Teacher: What do you mean?***
>
> ***Fatimah: The response of the body to the heat will change ... different from the human whose temperature is thirty seven ... his set point.***
>
> ***Teacher: Mmhmm.***

Fatimah: You mean his set point is thirty eight?

Teacher: Mmhmm.

Fatimah: It will change.

Teacher: Explain to me.

Fatimah: I mean like the instrument you told me about before ... the thermostat ... same way this one?

Teacher: Think about it?

Fatimah: I am recalling ... I do not know ... I do not remember.

Fatimah mentioned the analogy when she said *'I mean like the instrument you told me about before ... the thermostat ... same way this one?'*.

Although this is a correct response the student was not able to elaborate more on this. The following are her comments regarding what she thought about before stating her previous videotaped answer:

Teacher: What went in your mind regarding this question?

Fatimah: This question is difficult ...

Teacher: Do you want to see your answer maybe ...

Fatimah: Yes.

The student saw her answer.

Fatimah: Here I was recalling the answer that you gave me ... I was saying what is the answer ... I am afraid that it is the instrument ... I said

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maybe this is the answer ... I said let me say it ... it maybe correct.

It is clear that Fatimah experienced difficulty in answering this question (the average score of all students who received the analogy on this particular question was about 1.7 out of 3). Her comments indicate that she felt or maybe guessed that the answer is related to the analogy I presented to her two days ago. Therefore, she mentioned the analogy without any elaboration. Nevertheless, Fatimah's answer and comments point out that (a) the student thought about and resorted to the analogy when faced with difficulty, and (b) she concluded or guessed that the solution to the situation, presented in the question in terms of the target, had a similar solution in terms of the vehicle.

Second Experiment

second insulin lesson.

Hakeem was the only student (out of the 5 students who received the emigration analogy in the second experiment) to mention the analogy in an explanation or prediction question. He mentioned the analogy in his comments on his answer to the prediction question number 9. This is Hakeem's correct answer (he did not mention the analogy here):

Teacher: What do you think would happen if the glucose carriers in the cells become resistant and do not respond to the insulin effect? (Repeating the question)

Hakeem: I think the increase in the amount of sugar in the blood.

Teacher: Why did you say that?

Hakeem: Because there is no regulation ... glucose transporters regulate this substance in the blood.

Hakeem saw his previous answer on video and instantly described what he thought about before answering the question saying:

Hakeem: Let me tell you ... before I forget ... I remembered ... the emigration official ... you told me that travelers come to the hall ... an airplane ... the emigration employee if he is not present the place will be crowded ... I think this is what went in my mind.

Hakeem said that he recalled the emigration situation and thought about the situation presented in the question (glucose carriers are not functioning) but in terms of the emigration situation "the emigration employee if he is not present." Then he predicted that "the place will be crowded."

Examining Hakeem's answer presented earlier in which he said "I think the increase in the amount of sugar in the blood" indicates that Hakeem then used his prediction in the emigration situation and applied it to the insulin situation. This demonstrates that when students use the analogy to answer a prediction question, they use the vehicle part of the analogy (emigration) to make predictions about a

situation presented to them in terms of the target part of the analogy (insulin). Students then apply their prediction to the target.

Other Findings

1. Students' performances on new questions indicate a positive influence of using analogies to handle new situations.

Both in the insulin lesson and hypothalamus lesson, there were three new questions in the interview after instruction that were not asked in the interview before instruction. These questions represent the three categories of questions used in this study, namely recall, explanation, and prediction. Analyzing the results of these questions alone would indicate students' abilities to answer questions that are totally new to them, which demonstrates the influence of analogies on students' abilities to handle new situations in terms of targeted domain.

Table 5 summarizes the mean score of all Analogy and No Analogy groups on these three new questions in this study, including combining the results of the insulin and hypothalamus lesson. The following is a discussion of the results of each lesson. The comparisons between the Analogy and No Analogy groups are based on comparing the value of the mean score of each group on the three new questions.

Insulin lesson: The means of the three new questions indicate that the Analogy group outperformed the No Analogy group in the new recall and explanation questions, but not in the new prediction question, in which the No Analogy group did better. The largest difference between the two groups is

in the new recall question, which indicates again that the emigration analogy helped most in recalling information about the targeted insulin situation. The total average score of the three questions indicates that overall the emigration analogy helped students answer the new questions.

Table 5

Average Scores of each Group on the Three New Questions That Are in the Interview After Instruction But Not in the Interview Before Instruction

Insulin Groups

	Recall	Explanation	Prediction	Total
Analogy	4.5	2.75	2	9.25
No Analogy	3.37	2.13	2.62	8.12

Hypothalamus Groups

	Recall	Explanation	Prediction	Total
Analogy	3.15	1.18	1.5	5.83
No Analogy	3.31	0.75	1.68	5.74

The Two Groups Combined

	Recall	Explanation	Prediction	Total
Analogy	4.11	1.97	1.81	7.89
No Analogy	3.34	1.44	2.16	6.94

Second Insulin Groups

	Recall	Explanation	Prediction	Total
Analogy	3.9	1.7	1.7	7.3
No Analogy	2.3	2.2	1.3	5.8

Hypothalamus lesson: Examining the average scores of the three new questions indicates that the thermostat analogy had a positive influence on the ability of students to answer the new explanation question. The total average score does not indicate an overall positive influence of using the thermostat analogy in answering new questions.

The two groups combined: Combining the scores of the previous two groups indicates that there is an overall positive influence of using the emigration and thermostat analogies on students' abilities to answer new questions.

The second insulin lesson: The average scores of the three new questions indicate that the emigration analogy had a large positive influence on the ability of students to answer the new recall question. There is a slight positive influence on students' abilities to answer the new prediction question and a somewhat negative influence on answering the new explanation question. The total average score indicates a clear positive influence of using the emigration analogy to answer the new questions.

Overall, analogies seemed to help students answer new questions, and therefore to handle new situations.

2. Students' comments indicate that the analogy helped them recall information about the target domain.

At the end of the interview after questions, I asked students who received analogies about some of their perceptions and opinions regarding the analogy:

Question number 10: In answering the previous questions did you think about the (vehicle part of the analogy: the emigration or the thermostat) we talked about previously?

When did you think about it?

Why do you think you thought about it?

How did thinking about it influence your thinking?

One purpose of this question is to see how students perceived the influence of the analogy on their thinking. Analyzing the responses of all students who received analogies indicates that they think analogies helped them in two main ways (See Figure 7 below):

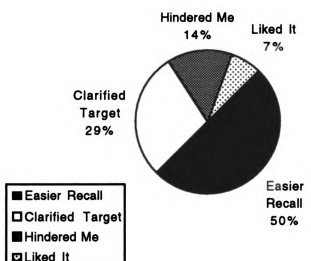


Figure 7. The Percentages of Students in Terms of How They Perceived the Influence of the Analogy

1. Made them recall information more easily.

2. Clarified and simplified the target principle by providing easier or more concrete example.

It is important to indicate that students' perceptions of how analogies influenced their thinking coincide with both quantitative analysis and qualitative analysis presented earlier: that analogies were most useful in recalling information about the target principle.

3. Students who did not use the analogy either failed to see the applicability of the analogy or they simply did not need the analogy.

In the first experiment, and in question 10, I asked students who said that they did not think about the analogy when they answered the interview questions about the reason for not thinking or recalling the analogy. Student responses indicated two reasons:

a. Students did not think about or mention the analogy because the questions were about the target principle (insulin or hypothalamus) and not about the vehicle (emigration or thermostat). This implies that students did not see the applicability of the analogy, and therefore did not use it to answer the interview questions (5 out of 7 mentioned this reason).

An example of this would be student number 10 from the hypothalamus treatment group, who said: "No ... there was no reason to tie it to the air conditioning ... my answers were related to the instruction ... the questions were not related to the air conditioning."

b. Students did not need the analogy either because they understood the lesson or had some information before about it (2 out of 7 mentioned this reason). An example of this would be student number 23 from the insulin treatment group, who said: "May be the one who will remember the airport is someone who first hears about this information ... but

because I had this information before ... it is true that the information may be wrong ... but it exists ... so the airport thing was not important because I knew the topic before."

4. Analogies helped to resist students incorrect explanations to the target domain.

There is evidence only in the second experiment, that analogies helped to eliminate students' incorrect or inaccurate explanations of how insulin regulated the level of sugar in blood. In instruction, I told students that insulin regulates the level of sugar in blood through increasing the number of active transporters in the cell wall. Transporters, in turn, will transport glucose from the blood into the cell.

However, 2 students from the control (No Analogy) in the second experiment mentioned different explanations of how insulin helped glucose to enter inside the cells. Both of their explanations came in response to the recall question: "Using your own words, and with as much detail possible, explain to me how the human body regulates the level of sugar in blood?"

Student number 3 said the following in response to the previous question:

> "When the human eats the food ... some food contain sugar materials ... some food contain complex sugars ... the glucose is a simple sugar ... the tissues are unable to absorb some of these sugar materials ... because of their complex chemical structure ... the role of insulin comes here ... insulin hormone ... the pancreas secretes it I think ... during digestion ... the pancreas secretes amounts of insulin that equate

> the amount of sugar ... so it reduces the complexity of sugar materials ... to make it easier for the tissues to absorb it ..."

The student suggested that the role of insulin is to reduce the complexity of glucose so it can be absorbed by the cells. Although this explanation is reasonable, it is not the correct scientific explanation of the phenomenon offered in instruction. On the other hand, the breakdown of complex materials to simpler ones to facilitate absorption is correct in the context of the digestion process of food. This show that the student incorrectly applied his knowledge of food digestion to how insulin regulates the level of glucose in the blood. This suggests that maybe after a while (one week in this experiment) students start to forget the explanations of the targeted domain that were presented to them in instruction, and will apply other plausible explanations from their previous experiences.

Student number 8 said the following to explain how glucose molecules get inside the cells:

> "... sugar as any other substance needs regulation ... so the pancreas starts to secrete certain amount of insulin to reduce the level of sugar in the blood ... this is through increasing the pores or the openings of the cell ... to absorb the largest amount of sugar".

Again, although the students' explanation is plausible, it is not the explanation offered in instruction. These

alternative explanations were found only in the control group, and only in the second experiment in which no drawings were used and the students were interviewed one week after instruction. There were no alternative explanations in the analogy group, which suggest that analogies helped students to maintain the correct explanation presented to them in instruction.

CHAPTER 5:

LIMITATIONS, DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

LIMITATIONS

The limitations of this study can be summarized by the following:

1. Most of the evidence on how analogies influence students' learning came from students' descriptions of their thinking process before they answered the questions of the interview after instruction, which is a form of self reporting. According to Ericsson and Simon (1984), some psychologists have strong doubts regarding the suitability of subjects' verbalization as scientific data, arguing that it may be useful for the discovery of thought processes but not for verifying them.
2. Some aspects of this study's methodology (interviews, double stimulus procedure) required the use of tutoring which has different dynamics compared to instruction in a regular classroom. This reduced the external validity of this study.
3. The use of volunteers to form the sample in this study put some limitations on generalizing the findings of this study to other students.
4. Researcher bias may have played a role in this study because I did the scoring of the interview after instruction

questions and I also transcribed and translated students' answers and comments.

5. Individualized interviews and the use of tape-recording and video may have exerted negative pressure on students, which may have negatively influenced their thinking processes and also their ability to describe their thinking.

6. The small sample size (32 students in the first experiment and 10 in the second) resulted small number of students in each group (8 in the first experiment and 5 in the second). This made it difficult to get significant differences in the t-test I used to see if analogies influenced students' learning.

DISCUSSION

The previous results can be summarized by the following three main points:

1. There were no significant differences in overall interview scores between Analogy and No Analogy groups. Removing illustrations from instruction and assessing students' performances after a longer period were in favor of the analogy group.
2. Students' scores, comments, and opinions suggest that analogies facilitated students' recall (by providing cues to recall the relevant information in the target principle), but it did not facilitate students' comprehension.
3. There is evidence that analogies have a positive influence in areas that were not the main concern of this study (e.g. to resist students incorrect explanations of the targeted phenomenon).

The following is a discussion of these results in relation to the two questions of this study:

1. Do analogies improve students' learning?
2. How do analogies influence students' learning?

Question I: Do Analogies Improve Students' Learning?

The first question of this study focused on whether using analogies in instruction facilitates students' learning. That there where no significant differences in this study between students who are taught using analogies and those who are taught without analogies suggests that analogies do not facilitate students' overall learning. These results support the results of one study out of the three studies reviewed earlier that dealt with the effectiveness of analogies in instruction. Gable and Sherwood (1980) reached similar results when they concluded that using analogies in instruction over a wide variety of topics for the entire school year did not improve students' achievement in comparison to control groups. Teachers in the treatment groups presented 10 chemical concepts in terms of analogies. In the control groups additional examples were presented instead of analogies. There were no significant differences in favor of the analogy groups compared to the control groups.

Yet, in the two studies in which differences were observed between the Analogy and No Analogy groups (Clement, 1993; Dupin & Johsua, 1989) the Analogy groups received hours of additional instruction that were not available to the control groups. In the Gable and Sherwood study, and in this study, the amount of time devoted for presenting analogies was much less. For instance, the additional time I

devoted for presenting the analogy was about 5 minutes (out 20 minutes of instruction). I did not devote more time because I wanted to act as a teacher in a regular classroom (like the teachers who participated in Gable & Sherwood study) who had to cover certain lessons in a specific period of time, among other constraints. Therefore the results of this study and previous research suggest that using analogies in instruction, in a way that they might be used in a regular classroom, will not yield significant improvements in students' performances.

This is not to say that analogies do not have a positive influence, since the mean score of the analogy group in this study was always higher than the mean score of the control group in all lessons. It could be for example that questions after instruction are not suitable to show the positive influence of using analogies in instruction on students' reasoning. Qualitative analysis of students' reasoning in different stages of instruction could be a better approach to show the subtle but important influence of analogies on students' thinking. In this study, for instance, qualitative analysis of students' descriptions of their thinking provided evidence for a positive influence of analogies. As I explained in the results section (under other findings), analogies helped students resist their incorrect explanations of the targeted principle.

In addition, four aspects of this study may have lessened the positive influence of analogies: the use of

illustrations, teaching a lesson that is not challenging enough, using an unfamiliar vehicle, and waiting for two days to assess performance.

1. The use of illustrations

The inclusion of illustrations depicting the targeted principle in the instruction of both the control and analogy groups helped all students to understand the targeted principle and decreased the need for the analogy. Research on the influence of illustrations on students' performances indicates that illustrations can improve students' learning, especially if the learner is able to see the connection between the illustrations and the verbal content (Levie & Lents, 1982). The positive influence of illustrations in this study comes from the comments of many students from both the Analogy and No Analogy groups. Most students mentioned that they recalled the illustrations and used them to answer the interview questions.

Furthermore, directly after the interviews I asked 6 students in the Insulin control group to mention one or two things from the instruction that were particularly helpful in answering the interview questions. 4 out of 6 students stated that the illustrations that I used in instruction helped them to answer the interview questions. This means that students in the Insulin control group benefited from the illustrations I presented and explained during instruction.

Although the effect of analogies may have been lessened by the illustrations, it can be argued that analogies and

illustrations function in a similar way. Both analogies and illustrations facilitate students' understanding by concretizing the targeted domain, and providing an organizing structure for the targeted information so that the relationships among its various parts are clarified and the important aspects are highlighted. Actually, illustrations can be viewed as one form of analogical representation. Shapes and lines in illustrations are used to analogically represent the elements and relationships in the targeted principle.

It follows that presenting illustrations to all students in this study helped all students understand the targeted principle in a similar way as if an analogy were presented to all students. In essence the experimental groups in the first experiment of this study received two analogies, one in the form of illustrations, and another in the form of illustrated analogy, while the control groups received one illustrated analogy. This might explain the results in the second experiment when illustrations were removed. The difference in performance between the experimental group and control group increased. This is because the experimental group received an analogy but the control did not.

2. Teaching a lesson that is not challenging enough

The second aspect of this study that might have lessened the influence of analogies is related to one of the two topics I used in this study, the Insulin lesson. Literature on analogies suggests that analogies are most useful when the

targeted domain is difficult for the learners (e.g., Gick & Holyoak, 1983; Duit, 1991). All students, both in the No Analogy and Analogy groups, did relatively well in the Insulin lesson, with an average score of about 20 out of 27. Therefore, the Insulin lesson may not be challenging enough to demonstrate the advantage of using analogies in instruction.

3. Using unfamiliar vehicle

The vehicle part of the analogy (how the thermostat works) which I used in the Hypothalamus lesson was not effective because students were not familiar with it. Literature on analogies emphasized the importance of using a familiar vehicle for effective results (e.g., Duit, 1991; Harrison & Treagust, 1993). learning through an analogy is based on the idea of using students' prior knowledge (represented by the vehicle), to facilitate the learning of new information. If the students are not familiar with the vehicle, that it is not part of their prior knowledge, then it will be difficult for students' to use the vehicle to learn the new information.

Unlike the emigration situation which seemed to be familiar to all students, the thermostat seemed much less familiar. This may be because the emigration situation is a real life situation experienced by most students, whereas the thermostat involves technical information the students took one time and then forgot. As indicated by the Hypothalamus lesson protocol (see Appendix A), I had to explain to the

students what a thermostat was, and how it worked, because all students said during instruction that they did not know or they had forgotten how a thermostat functioned. This, I think, decreased the effectiveness of the resulting analogy between how the hypothalamus functions and how the thermostat functions.

4. Waiting for two days to assess performance

Waiting for only two days to assess students' learning after instruction was not enough time for the positive influence of analogies to appear. This may have contributed to the more positive results in favor of the analogy in the second experiment, in which I waited for one week to assess students' performance. The difference between the Analogy and No Analogy groups increased markedly. There was a large difference in mean values on the prediction questions in favor of the Analogy group. There was also even a significant difference between the Analogy and the No Analogy group in the recall-type questions in favor of the Analogy group. This supports Radford's (1989) finding that analogies improve students' abilities on delayed recall in comparison to immediate recall. Yet, the difference between this study and Radford's study is that in this study, analogies were used in instruction and not in text.

Another factor that could influenced how students learned from analogies in this study is that the Kuwaiti students who participated in this study are not used to receive analogies as part of instruction. Students at Kuwait

university are used to "receive" facts from instructors with heavy emphasis on memorizing these facts for examinations. As the teacher in this study, many students expressed their admiration toward my efforts (specifically using an analogy) to make them understand the lesson. Many commented that they hoped that they were taught these lessons in the same way I taught them. This means that although using analogies in instruction is perceived as a positive thing by the students, it is not a common experience to them. This may influenced the effectiveness of analogies because students are not used to employ analogical reasoning when the dealt with new scientific phenomena.

In summary, the effectiveness of analogies in instruction depend upon several factors. Targeted domain difficulty, students' familiarity with the analogy, other instructional material used in instruction, and how and when students' performance are assessed are some factors highlighted by the results of this study. The following is a discussion of the results related to the second question of this study.

Question II: How do Analogies Influence Students' Learning?

The second question of this study is focused on how analogies influence student learning. I will discuss first how analogies influenced students' recall and then discuss their influence on students' understanding.

1. The influence of analogies on students' recall

From the analysis of students' comments and answers on the interview after instruction, I concluded that analogies were particularly helpful in facilitating students' abilities to recall the information mentioned in the instruction.

The evidence for this conclusion comes from all four data sources of this study:

a. Students' Scores on the Interview After Instruction.

Analogy groups in the Insulin lessons in the first and second experiment outperformed the No Analogy groups on recall type questions, and I found a significant difference between the two groups on recall-type questions in the second insulin lesson. It is important to keep in mind that in the second experiment there were only five students in each group. To find a significant difference with such a small number of individuals in each group means that the effect of using analogies is quite large, that is analogies greatly improved students' ability to recall information related to the targeted principle.

b. Students' Answers to the Interview After Instruction Questions.

Students spontaneously mentioned the vehicle part of the analogy as they answered recall questions.

c. Students' Comments Regarding What They Thought About Before Answering the Interview After Instruction Questions.

Students' descriptions of their thinking suggest that they recalled the vehicle part of the analogy and use it to recall the targeted domain.

d. Students' Opinions on How the Analogy Influenced Their Thinking.

Fifty percent (50%) of the students who used the analogy in their answers or comments said that analogies helped them to recall information mentioned in the instruction.

These findings support the hypothesis that students used the vehicle part of the analogy to provide them with cues about the targeted principle. Thus, they support the argument of Stepich and Newby (1988) who said that:

Using analogies facilitates efficient retrieval of information from memory by providing an effective retrieval cue. It can be used to initiate a reconstructive process of recall by providing a memorable image, along with other associated pieces of information. Recalling the analogy leads to recalling the "is like" relationship existing between the new information and a schema stored in memory. This triggers the recall of further aspects of the new information and so

on until the desired amount of detail has been recalled. (p.134).

Yet students' scores and their comments on the interview questions warrant a closer look. The scores of the interview recall questions indicate that there is a single question that contributed the most for the positive difference in recall questions' scores in favor of the analogy group. It is the first recall question. This question required students to use their own words to provide a detailed description of the targeted principle. Other questions asked students to recall specific information from the instruction (e.g., What is glucose?). In addition, the analysis of students' answers and comments regarding where the analogy groups mentioned the analogy (see p.80 in the results section) suggests that most students mentioned the analogy in the first recall question. As a matter of fact many students mentioned the analogy in this question only.

These data suggest that students were inclined to use analogies in recall questions that required them to articulate the big picture of the targeted domain, in contrast to recall questions that focused on a specific detail. Analogies then were helpful because they enabled students to encode the information, not as isolated bits of information but as integrated parts within an organized whole (Stepich & Newby, 1988). In the hypothesis section I said that the ability of learning the principle as a whole would be one of the ways by which analogies would improve

comprehension (indicated by students' scores of explanation and prediction questions). I think this applies to recall questions that require the articulation of the big picture, because, I think, the ability to articulate the big picture in detail is enhanced by students' understanding of the principle. Therefore, not all recall questions in this study assessed students' ability to memorize information presented to them in instruction, as most previous studies did (e.g., Radford, 1989; Donnelly and McDaniel, 1993). The first recall question in this study assessed students' comprehension in addition to their ability to recall.

I believe that the emigration analogy in the insulin lesson (in which the positive effect on the first recall question is observed) provided a story-like situation which facilitated the recall and the understanding of the different steps required to explain the targeted domain. Students remembered the emigration story and used it to remember how insulin regulated the level of sugar in the body.

2. The influence of analogies on students' comprehension

The results of this study contradicted my second hypothesis that students who received analogies would benefit more in explanation and prediction questions compared to recall questions. The basis of this hypothesis comes from the results of the Donnelly and McDaniel study (1993). The Donnelly and McDaniel study suggests that including analogies in text was helpful in improving students' answers on inferential questions (equivalent to explanation and

prediction questions in this study) but they had a negative effect on basic level questions (equivalent to recall-type question in this study). Donnelly and McDaniel argued that analogies diverted students' attention away from the details and information in the target principle because students were focusing on the familiar domain of the vehicle.

In the hypothesis section I argued that analogies would still be helpful because, unlike the Donnelly and McDaniel study, in this study the analogy was introduced by a teacher who emphasized the targeted domain through questioning. Yet the results of this study went beyond that suggesting that analogies were helpful in recall but not in comprehension questions. One factor that may have contributed to this result has to do with what I mentioned above regarding the four aspects of this study that lessened the positive influence of analogies (the inclusion of illustrations, a lesson that is not challenging enough, unfamiliar vehicle, and waiting for two days to assess performance).

The second factor is related to the fact that the teacher in this study (the researcher) did his best to explain the targeted principles to all students (in both the Analogy and No Analogy groups). In addition, instruction was interactive (students asked questions and provided answers during instruction) and individualized (which made it easier for students to focus on the instruction). It could be that under these circumstances and with the presence of other instructional strategies (illustrations and questioning in

this study), the analogy lost its advantage as a tool for improving students' comprehension because all students (in all groups) understood equally the targeted principle. Therefore, all students performed equally well on comprehension questions (explanation and prediction questions).

But why was the analogy able to help students in recall questions? As I said before, the first recall question was the key for this positive effect. It appears that analogies provided an overall schema for the targeted domain that was not provided by illustrations and was not undermined by the other conditions of this study mentioned above (e.g., using not enough challenging lesson and waiting for two days to assess students' performance).

Does this mean that analogies in this study were helpful in general recall questions only? Some other findings suggest otherwise. As I mentioned in the results section (under other findings) there is evidence that:

a. Analogies helped students deal with new situations. The total score of the Analogy groups in the three new questions (that were asked in the interview after instruction but not in the interview before instruction) was always higher than for the No Analogy groups.

b. Analogies helped students' resist explanations that contradicted with the explanation offered in instruction. There is evidence only in the second experiment, that the emigration analogy helped to eliminate students' incorrect or

inaccurate explanations of how insulin regulated the level of sugar in blood.

c. There is evidence in the second experiment that analogies helped students in answering prediction questions. Although the difference is not significant, the difference between the means (6.7 vs. 4.2 out of 9) clearly favors the Analogy group. This suggests that in the second experiment, the emigration analogy improved to some degree students' understanding of how insulin regulated the level of sugar in blood.

In summary, the influence of analogies in instruction is determined by a host of interrelated factors. The successful implementation of analogies as an instructional tool depends on careful consideration of all these factors. In this study analogies fell short on demonstrating their usefulness in improving students' understanding of the targeted principle. There is evidence that they improved recall and other aspects of students' reasoning.

CONCLUSIONS

Analogies influence students' reasoning in subtle but important ways that may not show in an overall assessment of students' performance. The successful implementation of analogies in instruction depends on the careful consideration of several factors related to the analogy, instruction, and students' prior knowledge. Familiar analogy and difficult targeted domain are two important factors (highlighted by this study) for the successful implementation of analogies in instruction.

RECOMMENDATIONS

1. The qualitative analysis of this study suggested that analogies influence students' reasoning in subtle but important ways, for instance, by resisting students' incorrect explanations of a phenomena. Therefore, there is a need for more qualitative research that is not limited to investigating the influence of using analogies in instruction on students' recall and comprehension, but goes beyond that to explore the more subtle influences of using analogies in instruction on students' reasoning of the targeted phenomena.
2. Since analogies influence students' reasoning in subtle (but important) ways, analogies positive influence may not appear in regular classroom tests. Therefore, teachers must not be discouraged if they noticed no improvements in students' test scores after using analogies.
3. For successful implementation of analogies in instruction, teachers and textbooks authors should use analogies that are familiar to the students who will receive the instruction, that is the vehicle part of the analogy is already part of students past experience. It is not enough that teachers "think" that the vehicle is familiar to students. Teachers must confirm that students are familiar

with the vehicle by asking students what they know about it before using it to explain the target phenomena.

4. The insulin lesson results indicated the importance of using analogies to teach difficult scientific topics. If the targeted topic is relatively easy for students to understand, then there is no need to use an analogy to teach that topic.

5. The results of the second experiment suggested that the positive influence of analogies will show more with the passage of time. Thus, there is a need to investigate the influence of using analogies in instruction after a long period of time.

6. In this study I used students' comments on their videotaped answers to understand how analogies influenced their thinking. To better understand how analogies influence students' reasoning, this and other more creative ways are needed to render students' thinking as they reason with analogies.

APPENDICES

APPENDIX A

APPENDIX A

INSULIN LESSON PROTOCOL

The following is the protocol I used to teach students the Insulin lesson. The text in **Bold** is what I said to the student. I started by explaining to the student what the general purpose of this study is, and what to expect as a participant in this study:

You are participating in a study of how people think and learn. We will meet twice, today and the day after tomorrow. Today I am going to ask you some questions about yourself and then I will ask you some questions about a topic related to Biology. Then I will explain that topic to you. I will meet you again the day after tomorrow to continue this experiment. I will tape-record and videotape the questioning part of today's meeting.

After turning on the tape recorder, I tried to build a relaxing atmosphere by asking the student the following questions:

1. What is your name? What is your major?

2. What courses you are taking this semester?

3. Do you have a hobby?

This lasted for approximately 5 minutes. Then, I tolled the student the following:

As I mentioned earlier, today I'm going to talk with you about a topic related to biology and it will be about how our bodies function. First I will ask you few questions. Then I will explain the topic to you.

Questions Before Instruction

Before asking the questions I tolled the student to follow this procedure in answering each question:

1. Hear the question and make sure that you understand the question (If necessary, I repeated the question to help students understand the question).

2. Take as much-time as necessary to think and prepare the answer.

3. Tell me if you are ready to answer.

4. Answer the question.

Now I will ask you few questions, please tell me all what you know about each question.

1. What causes the secretion of many hormones?

2. What is glucose? Why is it important to the human body?

3. Why do we feel tired after a period of not eating? Why did you say that?

4. Why do we advice people who have diabetes disease not to eat sweat food? Why did you say that?

5. What would be the level of insulin in blood after a long period of fasting? And why?

6. Diabetes patients receive daily injections to control their disease, what do you think is the substance used in these injections? Why did you say that?

(I turned off the tape recorder)

Instruction

I explained to the student the insulin lesson using one of two conditions:

1. Instruction without an analogy (control).
2. Instruction with an analogy (treatment).

I used Figures 8 and 9 with the control group. I used Figure 8, 9, and 10, with the analogy group. These figures were presented to students on 8" by 11" paper (same size as shown here). The following is how I explained the insulin lesson to a student in the No Analogy group (control) and then the Analogy group (treatment).

Instruction Without an Analogy (Control)

In the next few minutes I will explain to you how the human body maintains a relatively stable levels of glucose in the blood. Please feel free to ask questions or to make statements about the topic any time during instruction.

Hormones are molecules secreted by the endocrine glands into the blood and travel to other parts of the body. The secretion of certain hormones is controlled by the concentration of other chemicals in the blood.

Now, Can you name some of the endocrine glands in the body and the hormones that they produce?

(I listened to student answer)

One of endocrine glands is the pancreas. Can you name any hormone secreted by the pancreas?

(I listened to student answer)

The pancreas secretes more than one hormone, today we will discuss one of most important hormones secreted by the pancreas which is insulin. Insulin is secreted in response to a high concentration level of a simple type of sugar? Do you know the name of this simple sugar?

(I listened to student answer)

Glucose, a simple sugar and an important product of food digestion. It is important because many cells in our body, especially the nervous system, drive its energy from glucose. Glucose level in the blood is highest in the period immediately following a meal. If glucose level remains high, this could lead to wasteful loss of glucose in the urine as well as losses of large volume of water. Insulin is the hormone that can prevent this situation. Can you tell me how?

(I listened to student answer).

The effect of insulin is to increase glucose uptake and use by cells and thus to lower the level of glucose in the blood. Look at this figure (showing the student Figure 8).

(I explained the steps in Figure 8 to the student)

So can you explain to me using this figure (Figure 8) **the role of insulin in regulating the concentration of glucose in blood?**

(I listened to the student answer)

But how exactly does insulin increase the glucose uptake and use by cells? Can you try telling me how?

(I listened to student answer)

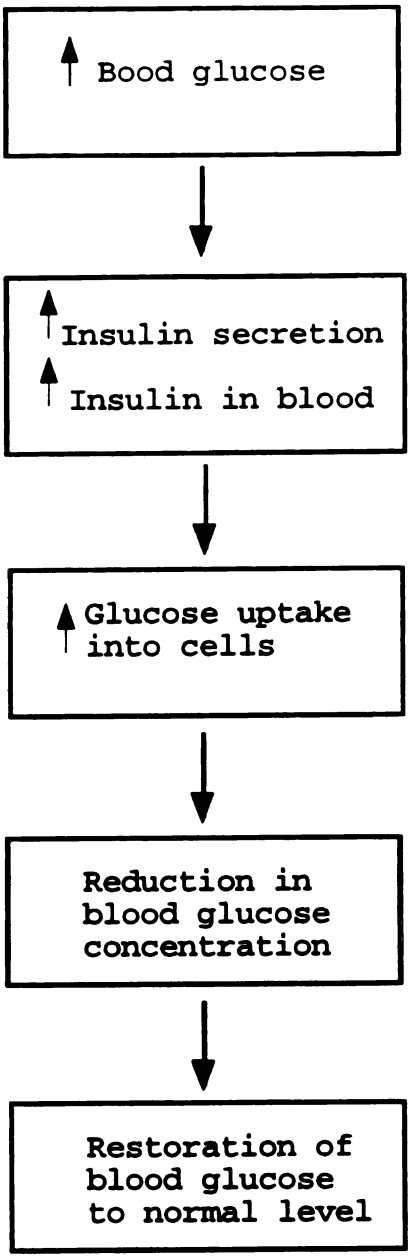


Figure 8. Role of Insulin in the Regulation of Blood Glucose Concentration

Insulin increase the entrance of glucose into cells by increasing the number of glucose transporters in the cell membrane.

Look at this figure (showing the student Figure 9 {a}), **You can see that after a meal, there is high glucose level in the blood, because glucose is one product of digestion.**

So what do you think will happen next inside the body given the situation of high glucose level?

(I listened to student answer)

(I showed student Figure. 9 {b})

Because of high glucose concentration, the pancreas secretes insulin into blood. Insulin reaches the cells and it increases glucose uptake by increasing the number of glucose transporters in the cell membrane.

What do you expect to happen to the level of glucose in blood? (I listened to student answer)

The level of glucose is low after insulin effect.

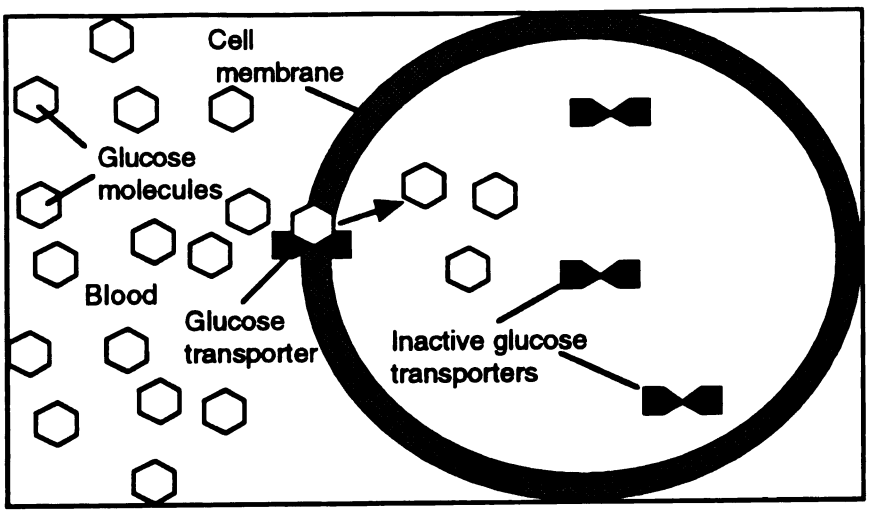
Using this figure (showing student Figure 9) **can you explain to me how insulin regulates the uptake of glucose by cells?**

(I listened to student answer)

So this is how insulin regulates glucose level in blood. Do you have any question or do you need any clarification regarding how the human body regulates the glucose level in blood.

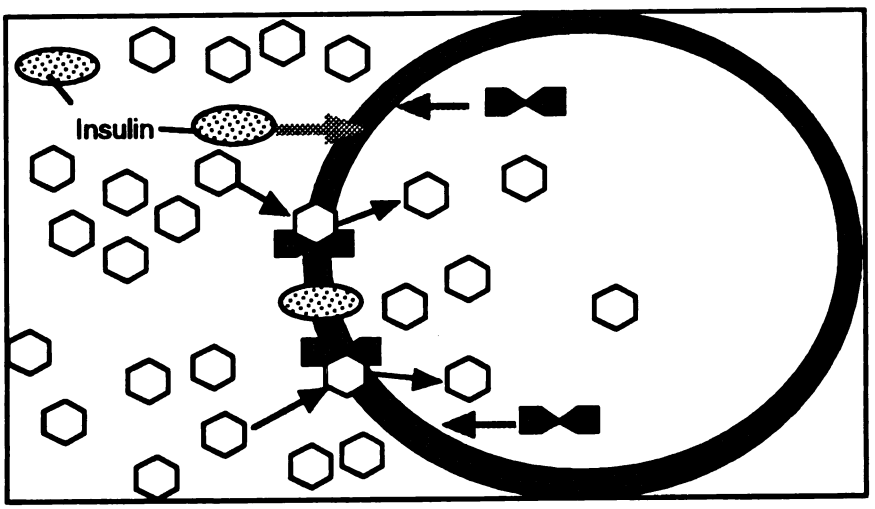
(a)

After a meal, high glucose level in the blood.



(b)

Insuline is secreted into blood. Insulin increases glucose uptake by increasing the number of glucose transporters in cell membrane



(c)

Glucose level in the blood is low after insulin effect.

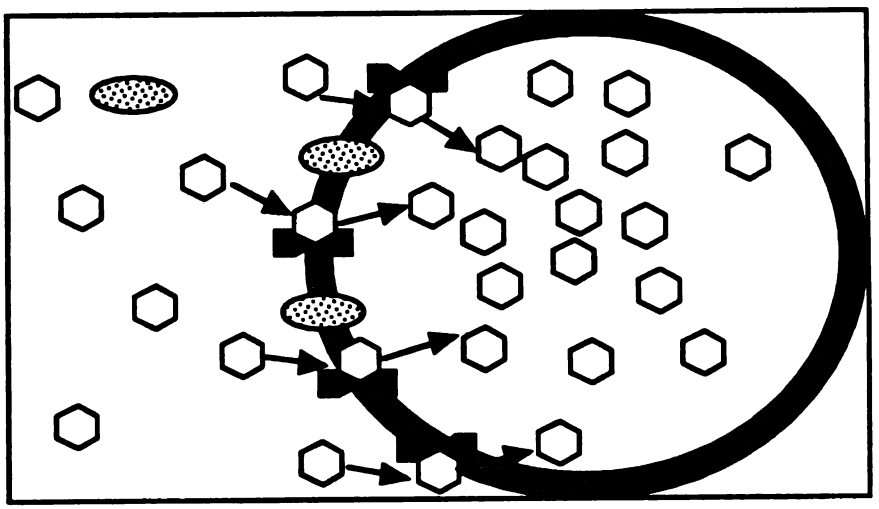


Figure 9. The Effect of Insulin to Stimulate Glucose Uptake into Cells.

(I listened to the student and respond to his questions).

This conclude our session today and I will see you the day after tomorrow.

(I set an appointment with the student two days after the instruction for the post instruction interview).

Instruction With Analogy (treatment)

In the next few minutes I will explain to you how the human body maintain a relatively stable levels of glucose in the blood.

Hormones are molecules secreted by the endocrine glands into the blood and they travel to other parts of the body. The secretion of many hormones is controlled by the concentration of chemicals in the blood that are not hormones.

Now, Can you name some of the endocrine glands in the body and the hormones that they produce?

(I listened to student answer)

One of endocrine glands is the pancreas. Can you name any hormone secreted by the pancreas?

(I listened to student answer)

The pancreas secret more than one hormone, today we will discuss one of most important hormones secreted by the pancreas which is insulin. Insulin is secreted in response to a high concentration level of a simple type of sugar? Do you know the name of this simple sugar?

(I listened to student answer)

Glucose, a simple sugar and an important product of food digestion. It is important because many cells in our body, especially the nervous system, drive its energy from glucose. Glucose level in the blood is highest in the period immediately following a meal. If glucose level remains high, this could lead to wasteful loss of glucose in the urine as well as losses of large volume of water. Insulin is the hormone that can prevent this situation. Can you tell me how?

(I listened to student answer).

The effect of insulin is to increase glucose uptake and use by cells and thus to lower the concentration of glucose in the blood. Look at this figure (showing the student Figure 8).

(I explained the steps in Figure 8 to the student)

So can you explain to me using this figure (Figure 8) **the role of insulin in regulating the concentration of glucose in blood?**

(I listened to the student answer)

But how exactly does insulin increases the glucose uptake and use by cells? can you try telling me how?

(I listened to student answer)

Insulin increase the entrance of glucose into cells by increasing the number of glucose transporters in the cell membrane.

Look at this figure (showing the student Figure 9 {a}), **You can see that after a meal, there is high glucose level in the blood, because glucose is one product of digestion.**

So what do you think will happen next inside the body given the situation of high glucose level?

(I listened to student answer)

(I showed student Figure 9 {b})

Because of high glucose concentration, the pancreas secretes insulin into blood. Insulin reaches the cells and it increases glucose uptake by increasing the number of glucose transporters in the cell membrane.

What do you expect to happen to the level of glucose in blood? (I listened to student answer)

The level of glucose is low after insulin effect.

So far the instruction was identical to the instruction in the control group. In the following part of the instruction I introduced the "Emigration analogy" to the student.

To help you understand this, I want you to tell me what would happen in the following situation. Lets say that a large airplane arrived in the airport from a foreign country. There was a lot of passengers in the airplane and all of them rushed to the emigration area. However, there was only one emigration officer on the counters. What would be the situation in the emigration area?

(I listened to student answer)

I showed the student Figure 10 and used it as I continue the instruction. I started by showing the student part (a) of Figure (10) while part (b) and (c) are covered by a sheet of paper.

There will be a lot of passengers waiting on lines to get through emigration. At this moment the emigration supervisors heard about the situation and they went to the emigration area. When they arrived they immediately called for more emigration officers to help passengers pass through (showing student Figure 10 (b)) **. Can you tell me what would be the situation in the emigration area after a period of time?**

(I listened to student answer)

Most passengers would pass through emigration and there will be few passengers in the emigration area. (directing students' attention to Figure 10 (c)).

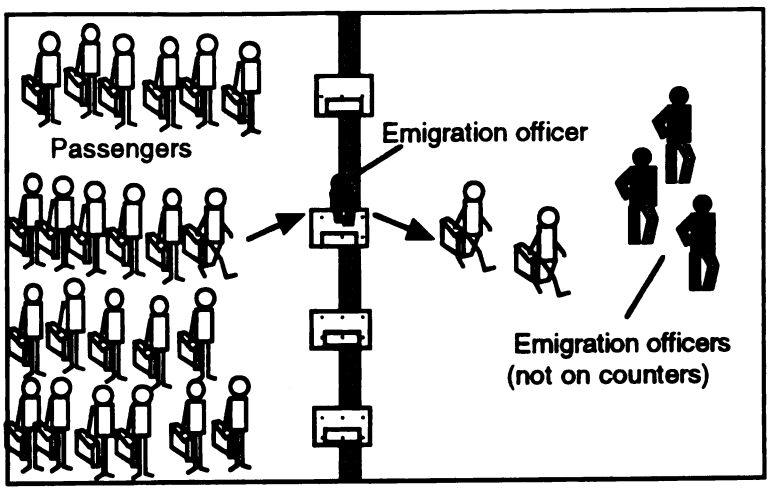
What happened in this situation is similar to the way human body regulates glucose level. Insulin decreases glucose level by increasing the number of glucose transporters like the emigration supervisors who decreased the number of people in the emigration area by calling additional emigration officers.

Using these figures (showing student Figure 9 and 10) **can you explain to me how insulin regulates the uptake of glucose by cells?**

So this is how insulin regulates glucose level in blood. Do you have any question or do you need any

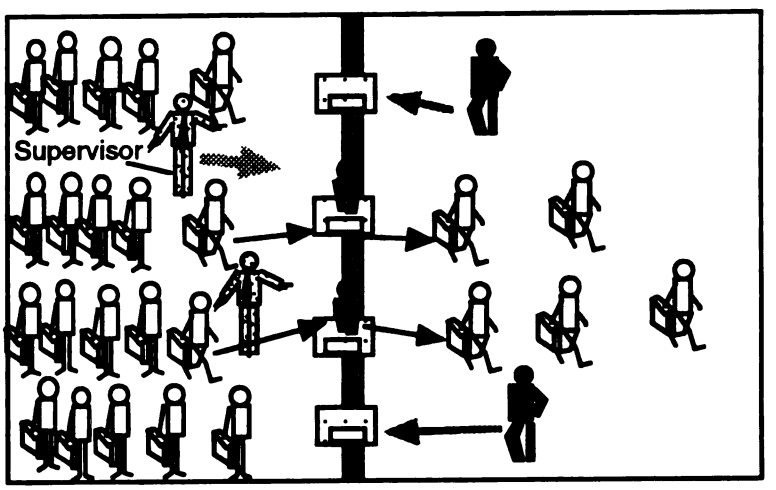
(a)

After the arrival of an airplane, many passengers are waiting in the emigration area.



(b)

Emigration supervisors arrive in the custom area and call for additional emigration officers. More emigration officers are on counters, therefor more passengers are passing through..



(c)

Few passengers are waiting in the emigration area.

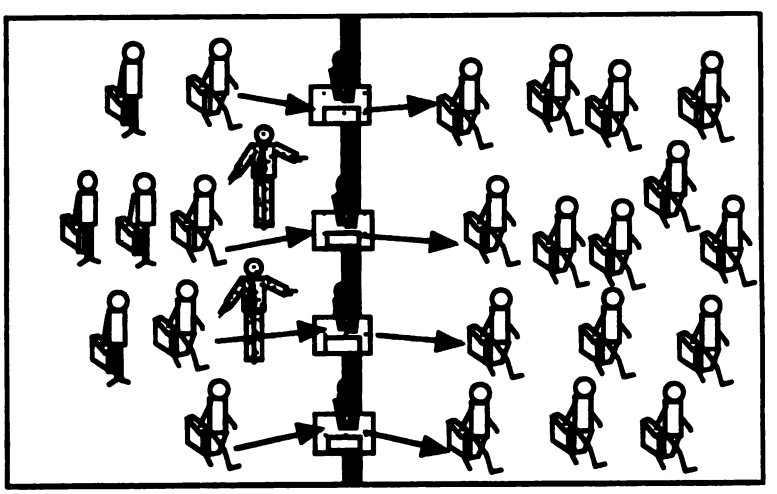


Figure 10: The Emigration Situation

clarification regarding how the human body regulates the glucose level in blood.

(I listened to the student and responded to his questions).

This conclude our session today and I will see you the day after tomorrow.

(I set an appointment with the student two days after the instruction for the post instruction interview).

Questions After Instruction

Two days after instruction I interviewed the student using the following questions. I tape recorded and video taped the interview. Before asking the questions I reminded the student that we will use the same procedure that we used during the interview before instruction.

I will ask you few questions, please tell me all what you know about each question:

1. Using your own words, explain to me how the human body regulates the level of sugar in blood?

2. Why do we feel tired after a period of not eating? Why did you say that?

3. What would be the level of insulin in blood after a long period of fasting? And why?

4. What causes the secretion of many hormones?

5. When an individual has a high glucose level in his blood, we say that he has diabetes. What do you think goes wrong in the human body to cause this disease? Why did you say that?

6. Diabetes patients receive daily injections to control their disease, what do you think is the substance used in these injections? Why did you say that?

7. What is glucose? Why is it important to the human body?

8. Why do we advice people who have diabetes disease not to eat sweat food? Why did you say that?

9. What do you think would happen if the glucose carriers in the cells become resistant and do not respond to the Insulin effect? Why did you say that?

The following question is only for the students who received the emigration analogy:

10. In answering the previous questions did you think about the emigration situation we talked about two days ago? If yes, when did you think about it? Did this influence your thinking? How?

After the interview I showed each student the video of his/her interview after instruction. I stopped (pause) the video just before student answer of each question, and asked him what s/he was thinking about. I also stopped the video after each answer and asked if the student can add more information regarding what he was thinking about before answering the question.

APPENDIX B

APPENDIX B

HYPOTHALAMUS LESSON PROTOCOL

The following is the protocol I used to teach students the Hypothalamus lesson. The text in **Bold** is what I said to the student. I started by explaining to the student what the general purpose of this study is, and what to expect as a participant in this study:

You are participating in a study of how people think and learn. We will meet twice, today and the day after tomorrow. Today I am going to ask you some questions about yourself and then I will ask you some questions about a topic related to Biology. Then I will explain that topic to you. I will meet you again the day after tomorrow to continue this experiment. I will tape-record and videotape the questioning part of today's meeting.

After turning on the tape recorder, I tried to build a relaxing atmosphere by asking the student the following questions:

1. What is your name? What is your major?

2. What courses you are taking this semester?

3. Do you have a hobby?

This lasted for approximately 5 minutes. Then, I tolled the student the following:

As I mentioned earlier, today I'm going to talk with you about a topic related to biology and it will be about how our bodies function. First I will ask you few questions. Then I will explain the topic to you.

Questions of the Interview before Instruction

Before asking the questions I told the student to follow this procedure in answering each question:

1. Hear the question and make sure that you understand the question (If necessary, I repeated the question to help students understand the question).

2. Take as much time as necessary to think and prepare the answer.

3. Tell me if you are ready to answer.

4. Answer the question.

Now I will ask you few questions, please tell me all what you know about each question.

1. How does the human body maintains its stable body temperature against the external changes in temperature?

2. We notice that when the human sweats in humid and hot days, he will feel more uncomfortable compared to only hot days with no humidity, why?

3. If we measured the body temperature of an individual every two hours throughout one day, are we going to get the same exact reading of his body temperature every time?

4. What is the name of the part or organ in the human body that controls the temperature of the human body?

5. We know that the normal temperature of the human body is thirty seven, it is called the set point. Lets say that an individual took certain medicine that suddenly changed the set point from thirty seven to thirty eight or ninety eight, what do you think the reaction of the human body in this case?

6. Lets say that an individual has an accident which resulted in removing a portion of his brain. After the operation this individual experienced a disorder in sweat secretion. Why do you think this happened?

Instruction

I explained to the student the Hypothalamus lesson using one of two conditions:

1. Instruction without an analogy (control).
2. Instruction with an analogy (treatment).

I used Table 6 and Figure 11 with the control group. I used Table 6, and the Figures 11, 12 and 13, with the analogy group. These figures were presented to students on 8" by 11" paper (same size as shown here). The following is how I explained the insulin lesson to a student in the No Analogy group (control) and then the Analogy group (treatment).

Instruction Without an Analogy (Control)

In the next few minutes I will explain to you how the human body maintains a relatively stable body temperature. Please feel free to ask questions or to make statements about the topic any time during instruction.

Animal species are often described as either "cold blooded" or "warm blooded". What do you think is meant by that?

(I listened to student answer)

Fish, reptiles, and invertebrates like insects are called cold blooded because their internal temperature depends on the temperature of the environment. On the other hand Birds and mammals, including humans, are called warm blooded. They evolved means of maintaining stable body temperatures over a range of environments.

Humans, produce heat within their bodies through metabolism. But how does a human keep its internal temperature nearly constant?

(I listened to student answer)

There are several processes through which the human body maintains a stable temperature.

(I showed and explained to the student Table 6; listing the different processes by which the human body keeps its temperature stable).

Can you now explain to me the processes through which the human maintains a stable body temperature?

(I listened to student answer)

Today we will talk in detail about only one of these processes which is sweating. What do you know about how the body maintain a stable body temperature through sweating?

(I listened to student answer)

Table 6

Mechanisms that Regulate the Body Temperature

	Response	
Mechanism	Body temperature below set point	Body temperature above set point
Blood vessels	Constrict so that less blood flows through skin reducing the amount of heat lost by radiation.	Enlarge so that more blood flows through skin increasing the amount of heat lost by radiation.
Sweat glands	Secret less fluids reducing amount of heat lost by evaporation.	Secret more fluids increasing amount of heat lost by evaporation.
Metabolism	Increases, thus producing more heat.	Decreases thus producing less heat.
Muscles	Become tense, induce shivering, increasing production of heat.	Become relaxed, decreasing production of heat.
Behavior	Move to a sunny place put on additional clothing, produce heat with fire	Move to a shad remove clothing, cool the environment by air conditioning.
Hair	Muscles contract, causing hair to stand increasing the amount of air trapped next to the body. This increase in insulation decreases the loss of body heat.	Muscles contract, causing hair to lie against the body decreasing the air trapped next to the body. This decrease in insulation increases the loss of body heat.

The human body maintains a stable body temperature through the Hypothalamus, which is part of our brain. The hypothalamus controls the body temperature. Do you know how this is done?

(I listened to student answer)

The hypothalamus regulate the body temperature by monitoring the temperature of the blood passing through it. When the temperature of the blood rises above the normal temperature, which is thirty seven degrees. The hypothalamus sends nerve messages to the sweat glands in the skin, causing them to produce more sweat. when the sweat evaporates heat is lost from the body, and the body temperature falls toward the normal temperature. Look at this figure,

(I explained to the student Figure 11)

Can you use this figure (Figure 11) **and explain to me how the human body regulate its temperature through the hypothalamus and the sweat glands.**

(I listened to student explanation)

So, this the way the hypothalamus and the sweat glands regulates the body temperature. Do you have any questions or do you need and clarification regarding this process?

(I listened to the student explanation and responded to his questions).

This conclude our session today and I will see you the day after tomorrow.

(I set an appointment with the student two days after the instruction for the post instruction interview).

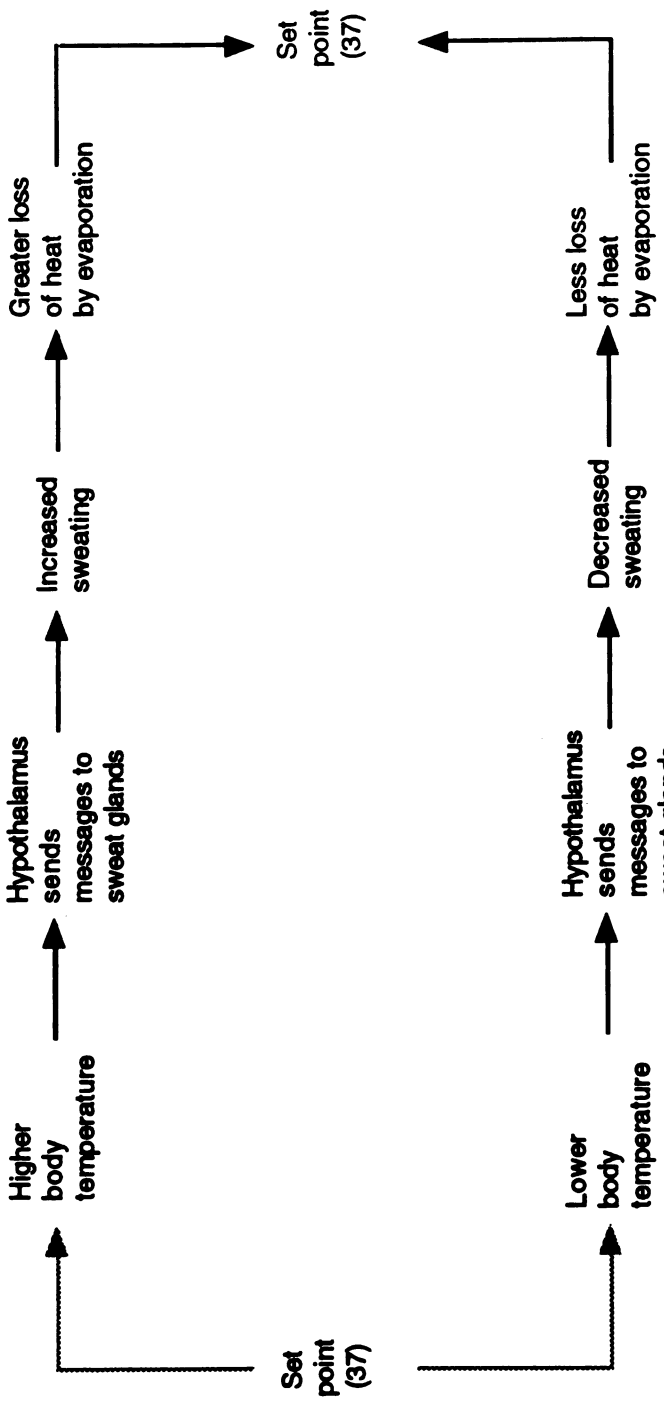


Figure 11. The Role of Sweating in Controlling Body Temperature

Instruction With Analogy (treatment)

In the next few minutes I will explain to you how the human body maintains a relatively stable body temperature. Please feel free to ask questions or to make statements about the topic any time during instruction.

Animal species are often described as either "cold blooded" or "warm blooded". What do you think is meant by that?

(I listened to student answer)

Fish, reptiles, and invertebrates like insects are called cold blooded because their internal temperature depends on the temperature of the environment. On the other hand Birds and mammals, including humans, are called warm blooded. They evolved means of maintaining stable body temperatures over a range of environments.

Humans, produce heat within their bodies through metabolism. But how does a human keep its internal temperature nearly constant?

(I listened to student answer)

There are several processes through which the human body maintains a stable temperature.

(I showed and explained to the student Table 6, listing the different processes by which the human body keeps its temperature stable).

Can you now explain to me the processes through which the human maintains a stable body temperature?

(I Listened to student answer)

Today we will talk in detail about only one of these processes which is sweating. What do you know about how the body maintain a stable body temperature through sweating?

(I Listened to student answer)

The human body maintains a stable body temperature through the Hypothalamus, which is part of our brain. The hypothalamus controls the body temperature. Do you know how this is done?

(I Listened to student answer)

The hypothalamus regulate the body temperature by monitoring the temperature of the blood passing through it. When the temperature of the blood rises above the normal temperature, which is thirty seven degrees. The hypothalamus sends nerve messages to the sweat glands in the skin, causing them to produce more sweat. when the sweat evaporates heat is lost from the body, and the body temperature falls toward the normal temperature. Look at this figure,

(I explained to the student Figure 11)

So far the instruction was identical to the instruction in the control group. In the following part of the instruction I introduced the "Thermostat analogy" to the student.

To help you understand this, can you answer the following question: Do you know how the central air conditioning is automatically turned on and off?

(I Listened to the student answer)

The working of central air conditioning is regulated through the thermostat? Do you know what is the thermostat and how it works?

(I Listened to the student answer)

The thermostat is a two-layered strip, look at this figure:

(I explained to the student Figure 12)

Notice that the way the thermostat work is similar to the way the hypothalamus work. Look at this figure:

(I explained to the student Figure 13)

Now, can you use these figures (Showing the student Figures 11 and 13) **and explain to me how both are similar in regulating the temperature?**

(I listened to the student answer)

So, this the way the hypothalamus and the sweat glands regulates the body temperature. Do you have any questions or do you need and clarification regarding this process?

(I listened to the student explanation and responded to his questions)

This conclude our session today and I will see you the day after tomorrow.

(I set an appointment with the student two days after the instruction for the post instruction interview).

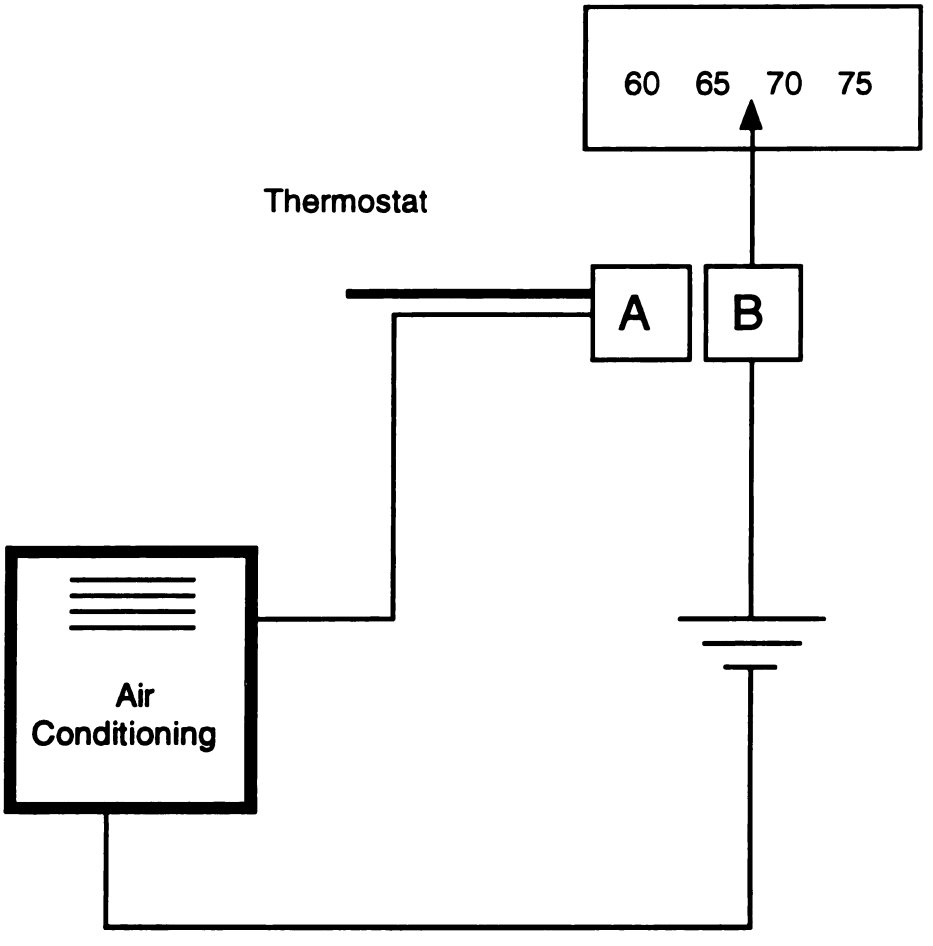


Figure 12. How The Thermostat works in the Central Air Conditioning

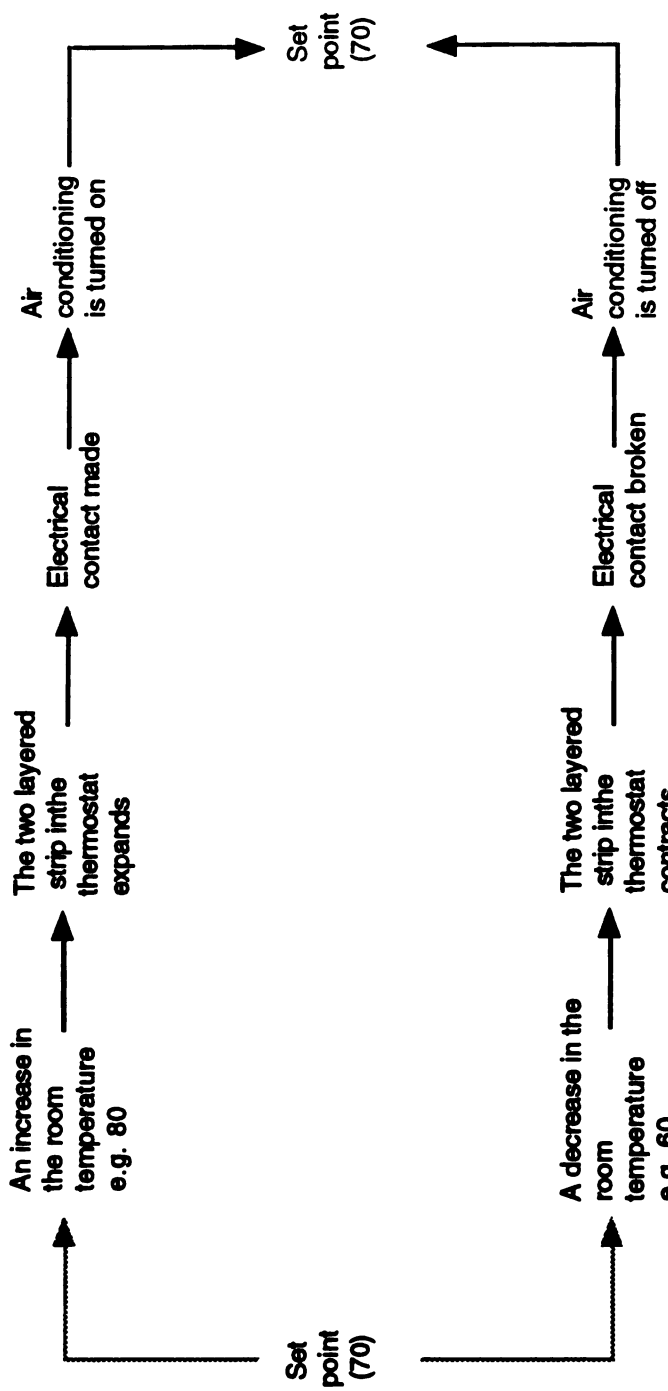


Figure 13. How the Thermostat Works

Questions After Instruction

Two days after instruction I interviewed the student using the following questions. I tape recorded and video taped the interview. Before asking the questions I reminded the student that we will use the same procedure that we used during the interview before instruction.

I will ask you few questions, please tell me all what you know about each question:

1. Using your own words, and with as much detail possible, explain to me how the human body maintains a relatively stable body temperature through the sweat glands?

2. We notice that when the human sweats in humid and hot days, he will feel more uncomfortable compared to only hot days with no humidity, why?

3. If we measured the body temperature of an individual every two hours throughout one day, are we going to get the same exact reading of his body temperature every time?

4. What is the name of the part or organ in the human body that controls the temperature of the human body?

5. The relationship between the change in body temperature and the response of the body to this change is described as a negative relationship. Why do you think it is described as a negative relationship?

6. We know that the normal temperature of the human body is thirty seven, it is called the set point. Lets say that an individual took certain medicine that suddenly changed the

set point from thirty seven to thirty eight or ninety eight, what do you think the reaction of the human body in this case?

7. How does the human body maintains its stable body temperature against the external changes in temperature? What are the ways?

8. This is a hypothetical question. In a hot day an individual puts a bag of ice below his head, Lets say that this resulted in cooling the blood that reaches the brain only. What do you think will happen?

9. Lets say that an individual has an accident which resulted in removing a portion of his brain. After the operation this individual experienced a disorder in sweat secretion. Why do you think this happened?

The following question is only for the students who received the emigration analogy:

10. In answering the previous questions did you think about the emigration situation we talked about two days ago? If yes, when did you think about it? Did this influence your thinking? How?

After the interview I showed each student the video of his/her interview after instruction. I stopped (pause) the video just before student answer of each question, and asked him what s/he was thinking about. I also stopped the video after each answer and asked if the student can add more information regarding what he was thinking about before answering the question.

APPENDIX C

APPENDIX C

SECOND INSULIN LESSON PROTOCOL

The protocol of the interview before instruction is not included here because it is identical to the protocol of the interview before instruction in the first insulin lesson. The protocol below starts from the Instruction presented to the Analogy and No Analogy groups. The text in '**Bold**' is what I said to the student.

Instruction Without an Analogy (Control)

In the next few minutes I will explain to you how the human body maintains a relatively stable levels of glucose in the blood. Please feel free to ask questions or to make statements about the topic any time during instruction.

Hormones are molecules secreted by the endocrine glands into the blood and travel to other parts of the body. The secretion of certain hormones is controlled by the concentration of other chemicals in the blood.

Now, Can you name some of the endocrine glands in the body and the hormones that they produce?

(I will listen to student answer)

One of endocrine glands is the pancreas. Can you name any hormone secreted by the pancreas?

(I will listen to student answer)

The pancreas secretes more than one hormone, today we will discuss one of most important hormones secreted by the pancreas which is insulin. Insulin is secreted in response to a high concentration level of a simple type of sugar? Do you know the name of this simple sugar?

(I will listen to student answer)

Glucose, a simple sugar and an important product of food digestion. It is important because many cells in our body, especially the nervous system, drive its energy from glucose. Glucose level in the blood is highest in the period immediately following a meal. If glucose level remains high, this could lead to wasteful loss of glucose in the urine as well as losses of large volume of water. Insulin is the hormone that can prevent this situation. Can you tell me how?

(I listened to student answer).

The effect of insulin is to increase glucose uptake and use by cells and thus to lower the level of glucose in the blood. Let me explain this more, after a meal, there will be high glucose level in the blood, this is because glucose is an important product of digestion as we said earlier. High glucose level will cause the pancreas to secret insulin hormone. Insulin will increase glucose uptake into the cells. As a result the level of glucose in the blood is reduced, and this will restore blood glucose to its normal level.

So can you explain to me the role of insulin in regulating the concentration of glucose in blood?

(I listened to the student answer)

But how exactly does insulin increase the glucose uptake and use by cells? Can you try telling me how?

(I listened to student answer)

Insulin increase the entrance of glucose into cells by increasing the number of glucose transporters in the cell membrane.

You see, after a meal, there is high glucose level in the blood. What do you think will happen next inside the body given the situation of high glucose level?

Because of high glucose concentration, the pancreas secretes insulin into blood. Insulin reaches the cells and it increases glucose uptake into the cells by increasing the number of glucose transporters in the cell membrane. So there will be more glucose transporters that transport glucose from the blood to inside the cells. Therefore more glucose will inter the cells.

What do you expect to happen to the level of glucose in blood? (I listened to student answer)

The level of glucose is low after insulin effect.

can you explain to me how insulin regulates the uptake of glucose by cells?

(I listened to student answer)

So this is how insulin regulates glucose level in blood. Do you have any question or do you need any clarification regarding how the human body regulates the glucose level in blood.

(I will listen to the student and respond to his questions).

This conclude our session today and I will see you one week from now.

(I will set an appointment with the student one week after the instruction for the post instruction interview).

Instruction With Analogy (treatment)

In the next few minutes I will explain to you how the human body maintain a relatively stable levels of glucose in the blood.

Hormones are molecules secreted by the endocrine glands into the blood and they travel to other parts of the body. The secretion of many hormones is controlled by the concentration of chemicals in the blood that are not hormones.

Now, Can you name some of the endocrine glands in the body and the hormones that they produce?

(I will listen to student answer)

One of endocrine glands is the pancreas. Can you name any hormone secreted by the pancreas?

(I will listen to student answer)

The pancreas secret more than one hormone, today we will discuss one of most important hormones secreted by the pancreas which is insulin. Insulin is secreted in response to a high concentration level of a simple type of sugar? Do you know the name of this simple sugar?

(I will listen to student answer)

Glucose, a simple sugar and an important product of food digestion. It is important because many cells in our body, especially the nervous system, drive its energy from glucose. Glucose level in the blood is highest in the period immediately following a meal. If glucose level remains high, this could lead to wasteful loss of glucose in the urine as well as losses of large volume of water. Insulin is the hormone that can prevent this situation. Can you tell me how?

(I listened to student answer).

The effect of insulin is to increase glucose uptake and use by cells and thus to lower the concentration of glucose in the blood. Let me explain this more, after a meal, there will be high glucose level in the blood, this is because glucose is an important product of digestion as we said earlier. High glucose level will cause the pancreas to secret insulin hormone. Insulin will increase glucose uptake into the cells. As a result the level of glucose in the blood is reduced, and this will restore blood glucose to its normal level.

So can you explain to me the role of insulin in regulating the concentration of glucose in blood?

(I listened to the student answer)

But how exactly does insulin increase the glucose uptake and use by cells? Can you try telling me how?

(I listened to student answer)

Insulin increase the entrance of glucose into cells by increasing the number of glucose transporters in the cell membrane.

You see, after a meal, there is high glucose level in the blood. What do you think will happen next inside the body given the situation of high glucose level?

Because of high glucose concentration, the pancreas secretes insulin into blood. Insulin reaches the cells and it increases glucose uptake into the cells by increasing the number of glucose transporters in the cell membrane. So there will be more glucose transporters that transport glucose from the blood to inside the cells. Therefore more glucose will inter the cells.

What do you expect to happen to the level of glucose in blood? (I will listen to student answer)

The level of glucose is low after insulin effect.

So far the instruction is identical to the instruction in the control group. In the following part of the instruction I introduced the "Emigration analogy" to the student.

To help you understand this, I want you to tell me what would happen in the following situation. Lets say that a large airplane arrived in the airport from a foreign country. There was a lot of passengers in the airplane and all of them rushed to the emigration area. However, there was only one emigration officer on the counters. What would be the situation in the emigration area?

(I listened to student answer)

There will be a lot of passengers waiting on lines to get through emigration. At this moment the emigration supervisors heard about the situation and they went to the emigration area. When they arrived they immediately called for more emigration officers to help passengers pass through. Can you tell me what would be the situation in the emigration area after a period of time?

(I listened to student answer)

Most passengers would pass through emigration and there will be few passengers in the emigration area.

What happened in this situation is similar to the way human body regulates glucose level. Insulin decreases glucose level by increasing the number of glucose transporters like the emigration supervisors who decreased the number of people in the emigration area by calling additional emigration officers.

Can you explain to me how insulin regulates the uptake of glucose by cells?

So this is how insulin regulates glucose level in blood. Do you have any question or do you need any clarification regarding how the human body regulates the glucose level in blood.

(I listened to the student and respond to his questions).

This conclude our session today and I will see you one week from today

(I set an appointment with the student one week after the instruction for the post instruction interview).

Questions After Instruction

One week after instruction I interviewed the students using the following questions. I tape recorded and video taped the interview. Before asking the questions I reminded the student that we will use the same procedure that we used during the interview before instruction.

I will ask you few questions, please tell me all what you know about each question:

1. Why do we feel tired after a period of not eating?

2. How do you describe the level of insulin hormone in the blood after a period of not eating?

3. Using your own words, and with as much detail possible, explain to me how the human body regulates the level of sugar in blood?

4. When an individual has a high glucose level in his blood, we say that he has diabetes. What do you think goes wrong in the human body to cause this disease?

5. Diabetes patients receive daily injections to control their disease .. what do you think is the contents of in these injections?

6. What causes the secretion of many hormones?

7. Why do we advice people who have diabetes disease not to eat sweet food?

8. What do you think would happen if the glucose carriers in the cells become resistant and do not respond to the Insulin effect?

9. What is glucose? Why is it important to the human body?

The following question is only for the students who received the emigration analogy:

10. In answering the previous questions did you think about the emigration situation we talked about two days ago? If yes, when did you think about it? Did this influence your thinking? How?

After the interview I showed each student the video of his/her interview after instruction. I stopped (pause) the video just before student answer of each question, and asked him what s/he was thinking about. I also stopped the video after each answer and asked if the student can add more information regarding what he was thinking about before answering the question.

APPENDIX D

APPENDIX D

MODEL ANSWERS FOR THE INSULIN LESSON

The following are the model answers that I used to score students answers for the Insulin lesson interview questions. I will first state the question and then its' answer.

Q.1. Using your own words, and with as much detail possible, explain to me how the human body regulates the level of sugar in blood?

Answer

Statements of information mentioned in instruction:

After a meal, there will be high glucose level in the blood, because glucose is one product of digestion. Since there is high glucose concentration in blood, the pancreas secretes insulin into blood. Insulin reaches the cells and it increases glucose uptake by increasing the number of glucose transporters in the cell membrane. Insulin does this by activating the inactive transporters inside the cells to transport glucose from the blood into the cells. Therefore, the level of glucose will decrease after insulin effect and return to its normal level.

Q.2. Why do we feel tired after a period of not eating?

Answer

Statement of the likely cause:

We feel tired because of insufficient glucose level in the blood or in the cells which is a major source of energy to the human body.

Statement of how the principle is used:

Since glucose comes from the digestion of food, therefore, a period of fasting will cause a drop in the level of glucose in the blood which means low energy.

Q.3. What would be the level of insulin in blood after a long period of fasting?

Answer

The likely result:

The concentration of Insulin will be low.

Explanation in terms of the principle:

Because after fasting the level of glucose in blood is low, and low glucose levels will not trigger the secretion of Insulin from the Pancreas.

Q.4. What causes the secretion of many hormones?

Answer

Statements of information mentioned in instruction:

The secretion of many hormones is controlled by the increase or decrease in the concentration of other chemicals in the blood.

(Q.5) When an individual has a high glucose level in his blood, we say that he has diabetes. What do you think goes wrong in the human body to cause this disease?

Answer

Statement of the likely cause:

High glucose level may result from insufficient amount of insulin secreted by the pancreas or from relative lack of response by target cells to insulin.

Statement of how the principle is used:

Insulin effect is to increase glucose uptake and use by the cells, thus lowering the level of glucose in blood. Since diabetes patients have high level of glucose in their blood then their must be something wrong regarding the presence or influence of insulin, that is it may be insufficient or ineffective.

(Q.6) Diabetes patients receive daily injections to control their disease, what do you think is the contents of in these injections?

Answer

The likely result:

It contain insulin hormone.

Explanation in terms of the principle:

Insulin effect is to increase glucose uptake and use by the cells, thus lowering the level of glucose in blood. Since diabetes patients have high glucose level, they receive insulin injections to lower their glucose level.

(Q.7) What is glucose?

Answer

Statements of information mentioned in instruction:

A simple type of sugar.

Why is it important to the human body?

Answer

Statements of information mentioned in instruction:

It is important because many cells in our body, especially the nervous system, drive its energy from glucose.

(Q.8) Why do we advice people who have diabetes disease not to eat sweet food?

Answer

Statement of the likely cause:

Because diabetes patients already have high glucose level in their blood and more glucose that comes from the sweet food may have dangerous effects on their health.

Statement of how the principle is used:

Diabetes patients have high glucose level because of insufficient or ineffective insulin that can not deal with normal amounts of glucose. Sweet food contain high amounts of glucose which will further increase the level of glucose in the body of diabetes patients and have harmful effects.

(Q.9) What do you think would happen if the glucose carriers in the cells become resistant and do not respond to the Insulin effect?

Answer

The likely result:

Glucose level in blood will become high.

Explanation in terms of the principle:

Insulin decreases the level of glucose in blood by increasing the number of glucose transporters in the cell membrane which transport glucose from the blood to inside the cell. Insulin increase the transporters number by activating the inactive transporters in the cell. If these transporters do not respond to insulin, then there will be no increase in

the number of transporters in the cell membrane which leads to high glucose level in the blood.

APPENDIX E

APPENDIX E

MODEL ANSWERS FOR THE HYPOTHALAMUS LESSON

The following are the model answers that I used to score students answers for the Insulin Hypothalamus interview questions. I will first state the question and then its' answer.

Q.1. Using your own words, and with as much detail possible, explain to me how the human body maintains a relatively stable body temperature through the sweat glands?

Answer

Statements of information mentioned in instruction:

The human body maintains a stable body temperature through the hypothalamus which is part of our brain. The hypothalamus acts as a temperature regulating center, monitoring the temperature of the blood passing through it. When the temperature of the blood rises above the set point, it stimulates the brains' temperature regulating center, the hypothalamus, to send messages to the sweat glands, causing them to produce more sweat, sweat evaporates and more heat is lost from the body, and the body temperature falls toward the set point. In the other hand, when the temperature of the blood decreases below the set point, the hypothalamus will send messages to the sweat glands causing them this time to produce less sweat or stop sweating, less sweat evaporates and less heat will be lost from the body. This will cause temperature to rise toward the set point.

Q.2. We notice that when the human sweats in humid and hot days, he will feel more uncomfortable compared to only hot days with no humidity, why?

Answer

Statement of the likely cause:

This is because humidity will reduce or hinder the evaporation of sweat, and this do not help cooling the body.

Statement of how the principle is used:

The body secrets sweat so that when it evaporates it will take the heat necessary for evaporation from the body, therefore this cools the body. Humidity means higher water vapor in the air and this hinder the evaporation of sweat and as a result hinder cooling the body.

Q.3. If we measured the body temperature of an individual every two hours throughout one day, are we going to get the same exact reading of his body temperature every time?

Answer

The likely result:

No, the readings will not be exactly the same every time. Temperature will slightly fluctuate up and down around the set point of thirty seven.

Explanation in terms of the principle:

The body regulates its temperature through the hypothalamus. The body temperature do increase and decrease according to the external temperature and human activity. The hypothalamus keeps the body temperature around the set point of thirty seven by invoking the mechanisms (sweat glands, blood vessels, ..) that will bring back body temperature toward the set point. Therefore, the readings will not be exactly thirty seven all the time.

Q.4. What is the name of the part or organ in the human body that controls the temperature of the human body?

Answer

Statements of information mentioned in instruction:

The name of the organ is hypothalamus.

Q.5. The relationship between the change in body temperature and the response of the body to this change is described as a negative relationship. Why do you think it is described as a negative relationship?

Answer

Statement of the likely cause:

The relationship is described as a negative relationship because there is a negative relation between the direction of temperature change and the direction of body response.

Statement of how the principle is used:

There is a negative relation between the direction of temperature change and the direction of body response because when the temperature increase above the set point the hypothalamus will try to reduce it. In the other hand, when it decrease below the set point the body will try to increase it.

Q.6. We know that the normal temperature of the human body is thirty seven, it is called the set point. Lets say that an individual took certain medicine that suddenly changed the set point from thirty seven to thirty eight or ninety eight, what do you think the reaction of the human body in this case?

Answer

The likely result:

The individual will shiver, his metabolism will increase, his blood vessels will constrict, sweating will stop, hair will erect.

Explanation in terms of the principle:

The set point is the point the hypothalamus tries to maintain. Therefore, when the medicine increased the set point and the temperature of the body become below the set point, the hypothalamus will activate the mechanisms that will increase the body temperature to the set point.

Q.7. How does the human body maintains its stable body temperature against the external changes in temperature? What are the ways?

Answer

Statements of information mentioned in instruction:

There are six mechanisms:

1. **Sweat glands.**
2. **Blood vessels.**
3. **Metabolism.**
4. **Muscles.**
5. **Behavior.**
6. **Hair.**

Q.8. This is a hypothetical question. In a hot day an individual puts a bag of ice below his head, Lets say that this resulted in cooling the blood that reaches the brain only. What do you think will happen?

Answer

The likely result:

The individual will stop sweating, his blood vessels will constrict, his metabolism will increase, hair will erect.

Explanation in terms of the principle:

The cold blood that reached the brain will pass through the hypothalamus and stimulate it to activate the mechanisms responsible for increasing body temperature.

Q.9. Lets say that an individual has an accident which resulted in removing a portion of his brain. After the operation this individual experienced a disorder in sweat secretion. Why do you think this happened?

Answer

Statement of the likely cause:

The operation resulted in removing part of the hypothalamus.

Statement of how the principle is used:

The hypothalamus regulates the sweat glands secretion. If part of it was removed in the operation a disorder in the secretion of sweat glands could occur.

APPENDIX F

APPENDIX F

TABLES OF STUDENTS' SCORES

Table 7

Scores of the Insulin Analogy Group on the Qustions After Instruction

	Question Number									
Stud.#	1	2	3	4	5	6	7	8	9	Total
31	3	2	3	2	2	3	2	2	1	20
9	5	2	3	1	2	2	1	3	3	22
17	5	3	3	2	3	3	2	2	2	25
23	5	2	3	2	3	3	2	3	2	25
5	4	0	0	0	3	2	0	1	1	11
19	4	3	3	1	3	3	2	2	3	24
27	5	2	3	0	3	2	2	2	2	21
2	5	3	0	2	3	2	2	3	2	22
Mean	4.5	2.12	2.25	1.25	2.75	2.5	1.62	2.25	2	21.25

Group *SD* = 1.60

Table 8

Scores of the Insulin No analogy Group on the Questions After instruction

	Question Number									
Stud.#	1	2	3	4	5	6	7	8	9	Total
15	4	3	0	1	0	3	1	1	2	15
26	4	3	3	2	3	2	2	3	3	25
16	3	3	3	2	0	3	2	2	3	21
3	1	3	0	1	3	2	2	3	3	18
32	5	2	0	0	2	3	1	3	3	19
11	2	3	0	0	3	2	2	2	3	17
21	4	3	3	0	3	3	2	2	3	23
1	4	2	3	2	3	3	2	3	1	23
Mean	3.37	2.75	1.5	1	2.12	2.62	1.75	2.37	2.62	20.12

Group *SD* = 1.22

Table 9

Scores of the Hypothalamus Analogy Group on the Qustions After Instruction

	Question Number									
Stud.#	1	2	3	4	5	6	7	8	9	Total
10	3	0	1.5	0	0.5	3	1.6	0	2.5	12.1
25	4	1	2.5	1.5	0	2.5	1.3	2	2.5	17.3
22	3	0	2	2	2.5	2.5	1.6	3	3	19.6
20	3	0	2	0	1	1	1.3	1.5	2.5	12.3
18	2.5	0	0	1	3	0.5	1.3	1	2.5	11.8
13	3	1	0	2	0	2	1.3	2.5	3	14.8
8	3	0	0	2	2	0.5	1	1	3	12.5
4	3.75	1.5	2.5	2	0.5	1	1.3	1	1.5	15.05
Mean	3.15	0.44	1.31	1.31	1.18	1.62	1.33	1.5	2.56	14.43

Group *SD* = 2.83

Table 10

Scores of the Hypothalamus No Analogy Group on the Qustions After Instruction

	Question Number									
Stud.#	1	2	3	4	5	6	7	8	9	Total
7	4.5	0	2	2	0	3	2	2	3	18.5
12	3.5	3	2.5	2	2.5	2.5	1.6	2.5	3	23.1
6	4	0	1.5	2	0.5	0	2	2.5	3	15.5
24	3.5	0	2	2	0.5	2.5	1.3	2.5	3	17.3
29	3.5	0	0	1.75	1	1	1.3	0.5	1.5	10.55
30	3	0	0	0	0.5	1	1	1	1.5	8
28	2.5	1	1.5	0.5	0.5	0.5	1.3	0	2	9.8
14	2	0.5	1.5	1	0.5	3	1.6	2.5	2	14.6
Mean	3.31	0.56	1.37	1.40	0.75	1.68	1.51	1.68	2.37	14.67

Group *SD* = 5.05

Table 11

Scores of the Insulin and Hypothalamus Analogy Groups Combined on the Questions After Instruction

	Question Number									
Stud.#	1	2	3	4	5	6	7	8	9	Total
10	3	0	1.5	0	0.5	3	1.6	0	2.5	12.1
25	4	1	2.5	1.5	0	2.5	1.3	2	2.5	17.3
22	3	0	2	2	2.5	2.5	1.6	3	3	19.6
20	3	0	2	0	1	1	1.3	1.5	2.5	12.3
18	2.5	0	0	1	3	0.5	1.3	1	2.5	11.8
13	3	1	0	2	0	2	1.3	2.5	3	14.8
8	3	0	0	2	2	0.5	1	1	3	12.5
4	3.7	1.5	2.5	2	0.5	1	1.3	1	1.5	15.05
31	3	2	3	2	2	3	2	2	1	20
9	5	2	3	1	2	2	1	3	3	22
17	5	3	3	2	3	3	2	2	2	25
23	5	2	3	2	3	3	2	3	2	25
5	4	0	0	0	3	2	0	1	1	11
19	4	3	3	1	3	3	2	2	3	24
27	5	2	3	0	3	2	2	2	2	21
2	5	3	0	2	3	2	2	3	2	22
Mean	3.8	1.2	1.7	1.2	1.9	2.0	1.4	1.8	2.2	17.84

Group *SD* = 5.07

Table 12

Scores of the Insulin and Hypothalamus No Analogy Groups Combined on the Questions After Instruction

	Question Number									
Stud.#	1	2	3	4	5	6	7	8	9	Total
7	4.5	0	2	2	0	3	2	2	3	18.5
12	3.5	3	2.5	2	2.5	2.5	1.6	2.5	3	23.1
6	4	0	1.5	2	0.5	0	2	2.5	3	15.5
24	3.5	0	2	2	0.5	2.5	1.3	2.5	3	17.3
29	3.5	0	0	1.7	1	1	1.3	0.5	1.5	10.55
30	3	0	0	0	0.5	1	1	1	1.5	8
28	2.5	1	1.5	0.5	0.5	0.5	1.3	0	2	9.8
14	2	0.5	1.5	1	0.5	3	1.6	2.5	2	14.6
15	4	3	0	1	0	3	1	1	2	15
26	4	3	3	2	3	2	2	3	3	25
16	3	3	3	2	0	3	2	2	3	21
3	1	3	0	1	3	2	2	3	3	18
32	5	2	0	0	2	3	1	3	3	19
11	2	3	0	0	3	2	2	2	3	17
21	4	3	3	0	3	3	2	2	3	23
1	4	2	3	1	3	3	2	3	1	23
Mean	3.3	1.6	1.4	1.1	1.4	2.1	1.6	2.0	2.5	17.40

Group *SD* = 5.04

Table 13

Scores of the Insulin Analogy Group on the Qustions After Instruction for the Second Experiment

	Question Number									
Stud.#	1	2	3	4	5	6	7	8	9	Total
1	1.5	3	4	0	1	0	1.5	3	2	16
4	2.5	2.5	2	0	3	0.5	2	1.5	2	16
6	2.5	3	4.5	3	1.5	1	2	0	2	19.5
9	2	3	5	2.5	3	0.5	3	2	2	23
10	1.5	2	4	3	3	0.5	2.5	2	2	20.5
Mean	2	2.7	3.9	1.7	2.3	0.5	2.2	1.7	2	19

Group *SD* = 2.97

Table 14

Scores of the Insulin No Analogy Group on the Qustions After Instruction for the Second Experiment

	Question Number									
Stud.#	1	2	3	4	5	6	7	8	9	Total
2	2	3	4	2.5	2.5	0	2.5	3	2	21.5
3	2.5	0	2.5	3	1.5	0.5	3	0	2	15
5	1.5	0	1	2	0	0.5	2.5	2	1.5	11
7	1.5	3	1	1.5	0	0	2	0	1.5	10.5
8	1.5	3	3	2	1.5	1	1	1.5	1	15.5
Mean	1.8	2.7	2.3	2.2	1.1	0.4	2.2	1.3	1.6	14.7

Group *SD* = 4.42

Table 15

The Scores and the Group Mean for the Insulin Analogy and No Analogy Groups on the Recall Questions

Analogy Group Question Number				No Analoogy Group Question Number			
1	4	7	Total	1	4	7	Total
3	2	2	7	4	1	1	6
5	1	1	7	4	2	2	8
5	2	2	9	3	2	2	7
5	2	2	9	1	1	2	4
4	0	0	4	5	0	1	6
4	1	2	7	2	0	2	4
5	0	2	7	4	0	2	6
5	2	2	9	4	2	2	8
		Mean	7.38			**Mean**	6.12
		Group *SD* =	1.68			Group *SD* =	1.55

Table 16

The Scores and the Group Mean for the Insulin Analogy and No Analogy Groups on the Explanation Questions

Analogy Group				No Analogy Group			
Question Number				Question Number			
2	5	8	Total	2	5	8	Total
2	2	2	6	3	0	1	4
2	2	3	7	3	3	3	9
3	3	2	8	3	0	2	5
2	3	3	8	3	3	3	9
0	3	1	4	2	2	3	7
3	3	2	8	3	3	2	8
2	3	2	7	3	3	2	8
3	3	3	9	2	3	3	8
		Mean	7.12			Mean	7.25
		Group *SD* =	1.55			Group *SD* =	1.80

Table 17

The Scores and the Group Mean for the Insulin Analogy and No Analogy Groups on the Prediction Questions

Analogy Group Question Number				No Analogy Group Question Number			
3	6	9	Total	3	6	9	Total
3	3	1	7	0	3	2	5
3	2	3	8	3	2	3	8
3	3	2	8	3	3	3	9
3	3	2	8	0	2	3	5
0	2	1	3	0	3	3	6
3	3	3	9	0	2	3	5
3	2	2	7	3	3	3	9
0	2	2	4	3	3	1	7
		Mean	6.75			**Mean**	6.75
		Group *SD* =	2.12			Group *SD* =	1.75

Table 18

The Scores and the Group Mean for the Hypothalamus Analogy and No Analogy Groups on the Recall Questions

Analogy Group Question Number				No Analogy Group Question Number			
1	4	7	Total	1	4	7	Total
3	0	1.6	4.6	4.5	2	2	8.5
4	1.5	1.3	6.8	3.5	2	1.6	7.1
2.5	2	1.6	6.1	4	2	2	8
3	0	1.3	4.3	3.5	2	1.3	6.8
3	1	1.3	5.3	3.5	1.75	1.3	6.55
3	2	1.3	6.3	3	0	1	4
3	2	1	6	2.5	0.5	1.3	4.3
3.75	2	1.3	7.05	2	1	1.6	4.6
		Mean	5.81			**Mean**	6.23
		Group *SD*	= 0.99			**Group *SD***	= 1.72

Table 19

The Scores and the Group Mean for the Hypothalamus Analogy and No Analogy Groups on the Explanation Questions

Analogy Group Question Number				No Analogy Group Question Number			
2	5	9	Total	2	5	9	Total
0	0.5	2.5	3	0	0	3	3
1	0	2.5	3.5	3	2.5	3	8.5
0	2.5	3	5.5	0	0.5	3	3.5
0	1	2.5	3.5	0	0.5	3	3.5
0	3	2.5	5.5	0	1	1.5	2.5
1	0	3	4	0	0.5	1.5	2
0	2	3	5	1	0.5	2	3.5
1.5	0.5	1.5	3.5	0.5	0.5	2	3
		Mean	4.19			**Mean**	3.69
		Group *SD*	= 0.99			**Group *SD***	= 2.01

Table 20

The Scores and the Group Mean for the Hypothalamus Analogy and No Analogy Groups on the Prediction Questions

Analogy Group				No Analogy Group			
Question Number				Question Number			
3	6	8	Total	3	6	8	Total
1.5	3	2.5	7	2	3	3	8
2.5	2.5	2.5	7.5	2.5	2.5	3	8
2	2.5	3	7.5	1.5	0	3	4.5
2	1	2.5	5.5	2	2.5	3	7.5
0	0.5	2.5	3	0	1	1.5	2.5
0	2	3	5	0	1	1.5	2.5
0	0.5	3	3.5	1.5	0.5	2	4
2.5	1	1.5	5	1.5	3	2	6.5
		Mean	5.5			**Mean**	5.44
		Group *SD* =	1.73			Group *SD* =	2.35

Table 21

The Scores and the Group Mean for the Combined Insulin and Hypothalamus Analogy and No Analogy Groups on the Recall Questions

Combined Analogy Group				Combined No Analogy Group			
Question Number				Question Number			
1	4	7	Total	1	4	7	Total
3	0	1.6	4.6	4.5	2	2	8.5
4	1.5	1.3	6.8	3.5	2	1.6	7.1
2.5	2	1.6	6.1	4	2	2	8
3	0	1.3	4.3	3.5	2	1.3	6.8
3	1	1.3	5.3	3.5	1.75	1.3	6.55
3	2	1.3	6.3	3	0	1	4
3	2	1	6	2.5	0.5	1.3	4.3
3.75	2	1.3	7.05	2	1	1.6	4.6
3	2	2	7	4	1	1	6
5	1	1	7	4	2	2	8
5	2	2	9	3	2	2	7
5	2	2	9	1	1	2	4
4	0	0	4	5	0	1	6
4	1	2	7	2	0	2	4
5	0	2	7	4	0	2	6
5	2	2	9	4	2	2	8
		Mean	6.59			Mean	6.18
		Group *SD* =	1.56			Group *SD* =	1.58

Table 22

The Scores and the Group Mean for the Combined Insulin and Hypothalamus Analogy and No Analogy Groups on the Explanation Questions

Combined Analogy Group				Combined No Analogy Group			
Question Number				Question Number			
2	5	9	Total	2	5	9	Total
0	0.5	2.5	3	0	0	3	3
1	0	2.5	3.5	3	2.5	3	8.5
0	2.5	3	5.5	0	0.5	3	3.5
0	1	2.5	3.5	0	0.5	3	3.5
0	3	2.5	5.5	0	1	1.5	2.5
1	0	3	4	0	0.5	1.5	2
0	2	3	5	1	0.5	2	3.5
1.5	0.5	1.5	3.5	0.5	0.5	2	3
2	2	2	6	3	0	1	4
2	2	3	7	3	3	3	9
3	3	2	8	3	0	2	5
2	3	3	8	3	3	3	9
0	3	1	4	2	2	3	7
3	3	2	8	3	3	2	8
2	3	2	7	3	3	2	8
3	3	3	9	2	3	3	8
			Mean 5.66				**Mean** 5.47
			Group *SD* = 1.97				Group *SD* = 2.61

Table 23

The Scores and the Group Mean for the Combined Insulin and Hypothalamus Analogy and No Analogy Groups on the Prediction Questions

Combined Analogy Group				Combined No Analogy Group			
Question Number				Question Number			
3	6	8	Total	3	6	8	Total
1.5	3	2.5	7	2	3	3	8
2.5	2.5	2.5	7.5	2.5	2.5	3	8
2	2.5	3	7.5	1.5	0	3	4.5
2	1	2.5	5.5	2	2.5	3	7.5
0	0.5	2.5	3	0	1	1.5	2.5
0	2	3	5	0	1	1.5	2.5
0	0.5	3	3.5	1.5	0.5	2	4
2.5	1	1.5	5	1.5	3	2	6.5
3	3	1	7	0	3	2	5
3	2	3	8	3	2	3	8
3	3	2	8	3	3	3	9
3	3	2	8	0	2	3	5
0	2	1	3	0	3	3	6
3	3	3	9	0	2	3	5
3	2	2	7	3	3	3	9
0	2	2	4	3	3	1	7
		Mean	6.12			Mean	6.09
		Group *SD* =	1.97			Group *SD* =	2.11

Table 24

The Scores and the Group Mean for the Insulin Analogy and No Analogy Groups on the Recall Questions for the Second Experiment

Analogy Group Question Number				No Analogy Group Question Number			
3	6	9	Total	3	6	9	Total
4	0	2	6	4	0	2	6
2	0.5	2	4.5	2.5	0.5	2	5
4.5	1	2	7.5	1	0.5	1.5	3
5	0.5	2	7.5	1	0	1.5	2.5
4	0.5	2	6.5	3	1	1	5
		Mean	6.4			**Mean**	4.3
		Group *SD*	= 1.24			**Group *SD***	= 1.48

Table 25

The Scores and the Group Mean for the Insulin Analogy and No Analogy Groups on the Explanation Questions for the Second Experiment

Analogy Group				No Analogy Group			
Question Number				Question Number			
1	4	7	Total	1	4	7	Total
1.5	0	1.5	3	2	2.5	2.5	7
2.5	0	2	4.5	2.5	3	3	8.5
2.5	3	2	7.5	1.5	2	2.5	6
2	2.5	3	7.5	1.5	1.5	2	5
1.5	3	2.5	7	1.5	2	1	4.5
Mean			5.9	**Mean**			6.2
Group *SD* =			2.04	Group *SD* =			1.60

Table 26

The Scores and the Group Mean for the Insulin Analogy and No Analogy Groups on the Prediction Questions for the Second Experiment

Analogy Group Question Number				No Analogy Group Question Number			
2	5	8	Total	2	5	8	Total
3	1	3	7	3	2.5	3	8.5
2.5	3	1.5	7	0	1.5	0	1.5
3	1.5	0	4.5	0	0	2	2
3	3	2	8	3	0	0	3
2	3	2	7	3	1.5	1.5	6
		Mean	6.7			**Mean**	4.2
		Group *SD* =	1.30			Group *SD* =	2.97

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