EXPLORING THE IMPACTS OF ANALOGIES ON COMPUTER HARDWARE

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ABSTRACT
In the last few decades, analogy, which is considered as a special case for reasoning, has attracted a great deal of attention from cognitive scientists. Although analogy was rarely applied in previous decades, now it is often considered by educators and researchers as a strategy to provide creative solutions and poetic writing (Paris & Glynn, 2004). Today, teaching models through analogy are used in different fields successfully and found to be beneficial for unobservable phenomena (Trey & Khan, 2008). Moving from the findings of previous studies, this study aims to explore the effects of detailed analogies on students' learning success in studying the working rationale and hardware components of the computer. 86 students in 1st and 2nd grades of Computer and instructional Technology Department volunteered to participate in the study. The sample was divided into two groups randomly: the control group who received the lectures without using analogies and the experimental group who were taught using detailed analogies. The data was collected through pre- and post-tests at the beginning and at the end of one academic term. The results of the analyses show that the students' success was significantly higher for the group taught via detailed analogies. Considering the low number of studies conducted to identify the effects of analogies on computer sciences learning, the findings of this present study are supposed to contribute to other studies in the field.
Keywords: teaching/learning strategies, computer learning strategies, analogy

INTRODUCTION

Examining pedagogical strategies which encourage students' conceptual understanding of the way the world works is very important. (Efendioğlu & Yelken, 2010; Trey & Khan, 2008) One of the strategies used to support this type of understanding is analogy. An analogy is "a comparison of identity or similarity of elements or relations, that is, on shared properties or identical relations" (Johansen, 2002, p.191). Gentner & Gentner (1983) highlight the importance of analogies in enhancing students' cognitive development by helping them to build on their previous knowledge.

Analogy is one of the most important tools used to accelerate conceptual change in scientific learning, and to develop teaching and learning scientific reasoning and inventions (Duit, 1991). In other words, it is an art of exact illustration of real life situations that provides learner the shortest and most effective way to reach learning objectives, and that facilitates his/her learning of concepts.

Throughout the history of science, analogies have been frequently used by scientists and science educators to explain fundamental elements such as the components of the cell (Glynn & Takahashi, 1998; Paris & Glynn, 2004), vocabulary and structure items when learning a foreign language (Klein, Piacente-Cimini & Williams, 2007), the laws of chemistry (Trey & Khan, 2008), the laws of physics (Duit, Roth, Komorek, Wilbers, 2001). Since analogies provide initial models for concepts they are also used by textbook authors to explain science concepts to students (Iding, 1997). Expressions like "similarly," "likewise," "just as," and "that is comparable to" are used by many authors to preface their analogies as indicators of analogies they are about to use. (Glynn & Takahashi, 1998)

Analogies can be utilized in two ways: verbal and pictorial. While diagrams, figures, and pictures are given to learners to teach the concepts that are hard to learn, verbal explanations which correspond to verbal analogies can support the understanding of the pictures. (Curtis & Reigeluth, 1984).

Analogy necessitates mapping of the elements and relationships of one domain into another by finding similarities and differences between them via reasoning which is a complex cognitive process Mapping is conducted among familiar structures (a set of physical and functional properties) of the analogy with new structures of the target. Researchers argue that this "mapping" process consists a comparison of knowledge already acquired in long-term memory with an individual's ongoing interaction with their environment and their empirical observations that engage sensory memory. Working memory serves as the arena for linking familiar and new structures where continuing repetitions and confirmations of the empirical observations foster cognitive processes. As a result of analogical reasoning, there can be an emergence of an enriched internal cognitive representation or mental model which may be subsequently stored in long-term memory. Mainly three hypotheses are suggested by this theory of analogical reasoning: "(1) analogies can provide a familiar basis for building a new concept, (2) analogical reasoning is supported by a dynamic correlation between new and familiar structural relations, and (3) an enriched mental model can be generated as a result of analogical reasoning" (Trey & Khan, 2008, p.520).

However, the results of the studies indicate that the use of analogies for instructional purposes is limited when students' analogical, or correlation reasoning, or visual imagery is constrained (O'Brien, 2002). Another difficulty may also emerge in case students cannot map the familiar onto new empirical phenomena while being engaged in scientific activity (and accessing images of concepts from their memory.

In this respect, for some researchers computer-based analogy can assist students with an explicit visualization of the relationship between the familiar and the new phenomena within a single multimedia environment. When students can come up with an accurate mapping between the analogy and the target, their analogical reasoning can be supported by a dynamic and visualized correlation of two structural relations (Trey & Khan, 2008). Therefore, analogies have been used successfully in many areas from sciences to social sciences. According to Wolters (1998), for example, analogies in science text designed to promote elaboration, can enhance the cognitive process of constructing relations between what is already known and what is new. This, ultimately, supports comprehension and increases intrinsically motivation.

Hamilton (1997) points out to the importance of elaboration as a way of using detailed analogies. He defines elaboration as ''any enhancement of information which clarifies or specifies the relationship between information to-be-learned and related information, i.e., a learner's prior knowledge and experience or contiguously presented information'' (Hamilton, 1997, p. 299). Elaboration can be activated by questions, objectives, personal examples, and other strategies (e.g., Martin & Pressley, 1991; Seifert, 1993; Willoughby, Wood, & Khan, 1994). Here, analogies are very effective since they can provide rich, redundant contexts for elaboration (Paris & Glynn, 2004).

Building relations between the existing and the new knowledge is crucial in interpreting students' learning as a process of conceptual change (Demastes, Good, & Peebles, 1996; Duit & Treagust, 1997; Hewson & Hewson, 1992; Strike & Posner, 1992). Familiar analogies (e.g., water is like electricity in some ways) are supposed to serve as early mental models to provide develop cognitively and learn more science and ultimately will evolve beyond these simple situated analogies, adopting more sophisticated and powerful explanatory models (Glynn & Duit, 1995; Iding, 1997; Lehrer & Schauble, 1998).

In computer sciences, because the concepts are so abstract, it is obvious that these concepts are almost impossible to be perceived with sense organs. Some different tools are needed for them to be understood. Because there are so many different hardware components and there are a lot of sub-components of these components, experts sometimes interpret them differently from each other, which causes students to form "misconceptions" (Brown, 1992). Since misconceptions can hinder understanding they should be avoided by analogies. The use of analogy is one of the methods that can be used in computer technologies because teaching students these difficult scientific topics through visual and real-life materials will be very effective. It has been reported that if students are actively involved and can link up the analogy and behavior, their misconceptions decrease (Brown, 1992; Silverstein, 2000).

To be able to avoid such problems, students can create their own analogies to enhance the conceptual change (Wong, 1993). For creating their own analogies, students should be both capable and willing to do it (Gabel & Sherwood, 1980). Otherwise, wrong sampling may cause misunderstanding of the concepts, and considering that this inaccurate information may be corrected really hard, the experts should use analogies really careful (Atav, Erdem, Yilmaz, & Gücüm, 2004)

One of the fastest developing one is informatics technologies. With the rapid developments in technology, new products are being introduced every day. In addition to the increasing number and function, it is also hard for students to understand the topics about computer hardware because they cannot be easily associated to real objects. That's why, using analogies for teaching these topics makes it easier for the students to understand and remember.

In this respect, this study aims to find out the effects of analogies used in different fields of computer sciences. Detailed analogies such as picture, simulation, etc. were used for teaching unobservable concepts in computer sciences. These detailed analogies were found to be useful in enhancing the students' learning.

The study searches answers to following research questions: 1) Can detailed analogies support student understanding of computer hardware learning? 2) What are students' views about learning with detailed analogy?

METHOD

Research Design

The study was conducted at Computer and Instructional Technology Department. The sample consisted of 86 volunteer (32 girls and 54 boys) students at the first and second grades. The students were divided into two groups, 43 in each group. The control group was taught the topics in traditional ways while the experimental group students via detailed analogies three hours a week during two months.

Students are supposed to know basic elements of computer hardware since they had a course called Information Technology in Education which teaches about hardware parts in 1st year. To measure their actual level of knowledge, a pre-test was applied to both groups. A post-test was then applied after a teaching period of two months. Students in experimental group were also requested to fill in a questionnaire.

While teaching computer hardware topics, electronic circuit parts were first given. While the control group was given the existing definitions and some figures, the experimental group was taught by using real-life samples. The samples' reliability was tested by taking experts' opinions. One of the samples is as shown in Figure 1.

Circuit Element: Capacitor

Control Group

A capacitor is an electrical or electronic component consisting of a pair of conductors separated by a dielectric (insulator). Also known as condenser, capacitor was invented in 18th century and has become one of the indispensable elements of electrical and electronic engineering which has great importance in the progression of technology. Capacitors are essential elements for all integrated electronic components and are widely used in storing electrical energy, controlling reactive power, switching between AC and DC.

Experimental Group

A capacitor is an electrical or electronic component consisting of a pair of conductors separated by a dielectric (insulator). To make this clearer, we will give an example from daily life. Imagine now a tap and a bucket under this tap and suppose that the water flowing from the tap is not fixed and also suppose that the water is cut off from time to time. If we turn on the tap completely while so little water is coming out, there would be a full flow of water and consequently the water would begin to overflow from the bucket. In case of any water cut off, we would also not have enough water while we will need it. Now imagine that we will build a tank to prevent this kind of problems and will let the water flow in this tank. Imagine also that we will put another tap at the bottom of this tank. Water flowing from the second tap would be fixed regardless water flow of the first tap. A capacitor, gives a fixed current to circuit components in the same way.

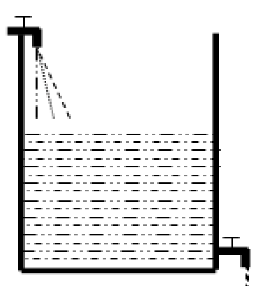


Figure 1. Teaching a Capacitor in Traditional Way and Via Analogies

After explaining electronic circuits to students, computer hardware units were introduced and the aim of producing these units was explained. These units were explained to experimental group as if they were human organs, as shown in Table 1.

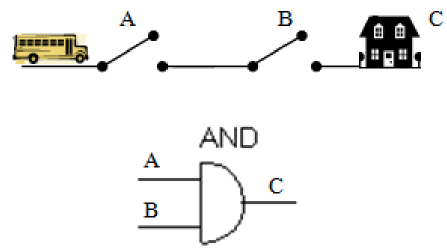
Table 1: Teaching Hardware Parts of a Computer via Human Body Analogy

Computer Hardware	Human Body Part
Keyboard + Mouse + Printer	Hand + Finger
Harddisk	Brain (Long Term Memory)
Ram	Brain (Short Term Memory)
CPU	Brain (Central Process)
Data Bus	Nervous System
Power Cable	Veins
Camera & Scanner	Eyes
Speaker	Mouth & Lip
Microphone	Ears

While teaching CPU, one of the computer hardware units, it was found that the students had the analogy that it is the brain of the computer. This information is both wrong and inadequate because human brain not only performs transactions but it also has much more functions such as memory, etc. This misconception made the students have the wrong idea that the information in the computer was stored in CPU.

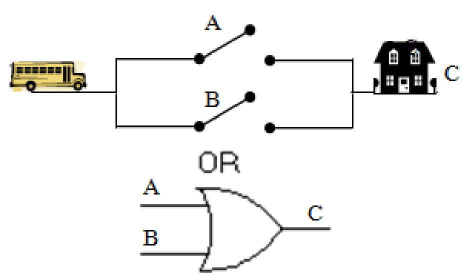
A school workbench was chosen as an analogy to teach differences between RAM and other storage volumes. Analogy; "let's imagine a model making. And now, let's imagine that we put materials we need on our workbench while making the model. In this manner, we could work quickly because we reach easily all materials. But after a while, we would not have enough places on the workbench as we will begin to build parts of the model and our work would slow down. Therefore, let's put the parts built in a larger and safer place, like a cupboard. We should also put the materials away before leaving the workroom to prevent damage to our materials. Otherwise the materials on workbench could be removed by cleaning persons because this workbench has been temporarily assigned to us. In this example, workbench is RAM and cupboard is hard drive. In other words, files we will need for a short period of time or smaller size files are stored in RAM. If we want to keep them permanently, we should store them in hard drives or in other permanent storage mediums. Some programs can run directly without installation while others need to be installed in hard drive. The reason for this is that we should store in larger places materials too big for the workbench which would limit our working place. Moreover, as we shut down all energy while leaving the room, the cleaning persons would remove all materials on the desktop. This example shows us that all information in RAM will be removed when the computer is shut down and that RAM is a temporary storage area"

While teaching logic gates, an analogy of bus and bridge was given. Analogy; "Logic gates are widely used in computers and electronics. In gates, we use codes 0 and 1. 1 means high input or output and 0 means low input or output. There are two basic gates; a) AND gate b) OR gate. Let's consider gates as a swing bridge and codes as a bus coming to school. AND gate, as shown in Figure 2, is a bus and has to come to school by crossing the bridges A and B. Both bridges should function well, namely at value 1, so that the bus comes to school. If the bridges A and B are 1 then the bus will be able to come to school; that is to say, C value will be 1. Even one of the two bridges does not function, namely, C value is 0, the bus will not be able to come to school. In that case, there would be no output current in the circuit. At least one bridge should function in OR gate. Even if one of the bridges does not function, the bus will be able to come to school by using the other bridge, as shown in Figure 3.



A	B	C
1	1	1
1	0	0
0	1	0
0	0	0

Figure 2. Analogy as and Gate



A	B	C
1	1	1
1	0	1
0	1	1
0	0	0

Figure 3. Analogy as or Gate

Data Sources
The effects of detailed analogies technique of teaching computer hardware concepts on students' academic success were examined. The pre-test consisting of information about computer hardware was applied. Moreover, the students were given an extra page with pre-test which sought for their personal information such as their high schools, sex, etc. The post-test was used for evaluating the scores of students once after the lecture has been given in traditional and detailed analogical methods. Additionally, in order to assess their opinion on analogy techniques, the post-test also featured a survey for students who were subjected to detailed analogical methods.

Data Analysis
The data was collected in March and April, 2009, and it was transferred to computer environment. The data then was analyzed using One Factor ANCOVA test on SPSS, and their frequencies and significances were calculated.

RESULTS
A total of 86 students -32 female and 54 male- have participated in the research. The students were divided into two groups consisting of 16 female and 27 male students each. The pre-test / final-test results acquired through statistical calculations have been shown in Table 2.

Table 2: Group Statistic

	Control Group		Experimental Group	
	Female Subjects	Male Subjects	Female Subjects	Male Subjects
Number of Subjects	16	27	16	27
Pre-test	34.37	34.07	33.12	33.88
Post-Test	57.18	55.92	73.12	82.22
Total Number	43		43	
Pre-test Total Score	35.69		36.39	
Post-Test Total Score	61.97		84.18	
Pre-test Post-test Difference	26.28		47.79	

The pre-test results showed that the average of students in control group was 35.69 % and that in experimental group had 36.39 %, as shown in Table 2. No significant difference was found between groups for pretest, $t_{(84)}$ = 0.176 (sig. = 0.861), $p > 0.05$, as shown in Table 3. This suggests homogeneous distribution between groups. According to pre and post-test results, the control group students rose their academic success in proportion of 26.28 %. The experimental group students who were taught the topic via detailed analogy increased their academic success in proportion of 47.79 % as shown in Table 2. These results show a significantly positive effect of detailed analogies on learning computer hardware units.

Table 3: Pretest Result (t-test)

		F	Sig.	T	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.
Pretest	Equal variances assumed	.20	.64	.17	84.00	.86	.58	3.31
	Equal variances not assumed			.17	83.53	.86	.58	3.31

Moreover, there was a significant difference between the elaborate analogy used for computer hardware learning and the posttest, $F_{(1\text{-}83)} = 34.14$ (sig. = 0.00), $p < 0.05$, as shown in Table 4. It was 61.97 % for the control group and 84.18 % for the experimental group.

Table 4: Post-Test Results

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	11353.84[a]	2	5676.92	17.59	.00
Intercept	56615.35	1	56615.35	175.46	.00
Pretest	413.14	1	413.14	1.28	.26
Group	11018.24	1	11018.24	34.14	.00
Error	26781.04	83	322.66		
Total	432000.00	86			
Corrected Total	38134.88	85			

[a]R Squared = .29 (Adjusted R Squared = .28)

In the interviews conducted with experimental group, they were asked to evaluate the detailed analogies used for teaching the topics. 90.68 % of the students (n=39) found it very good; 2.33% of them (n=1) found it good; 6.99% of the students (n=3) found this technique fair average. The students, who have achieved average scores, have reported that they have misinterpreted or failed to comprehend some analogies, which resulted in conceptual misunderstandings that led them to their results.

One of the students who found analogies very good stated that “in some forums on the Internet, CPU is stated as the brain of the computer. I always knew just like this. I always thought that all the operations in the computer were accomplished by the CPU, even the data was saved in the CPU. But now I know that CPU, RAM, HDD, etc. have different functions.” Another student said that I had not understood how 1 and 0 go from one card to another. But giving the example “the nerve cells” made it very clear for me. Besides, I now understand how computers still work when power cuts less than a second. Before condenser discharges, the main tap fills the bucket.”

The students in the control group were given several example analogies once after the post-test has been conducted and they were asked whether using analogies in lectures from that point on would be beneficial for them or not. 88.37% of the students (n=38) have reported that they definitely support the use of analogies in lectures while 9.30% (n=4) reported that it would not make any difference for them and 2.33% (n=1) reported that they do not want analogies. The students who were against analogies have been asked the reason of their statements and their answers were that they already knew the topics prior to the lecture and that was why they had scored high on the pre-test and the post-test.

DISCUSSION AND CONCLUSION

This study aims to find out whether detailed analogies support student understanding of computer hardware learning and tries to elicit students' opinions about learning via detailed analogy. In parallel with many previous studies (Klein, Cimini & Williams, 2007; Wang & Wu, 2008; Paris & Glynn, 2004; Trey & Khan, 2008; Tartwijk, Rijswijk, Tuithof & Driessen, 2008), the results of this study indicate that detailed analogies enhance students' learning of computer hardware topics.

The statistical analysis of the data shows that using detailed analogies in computer hardware is more beneficial than the traditional teaching methods. Moreover, it was found that analogies had a positive impact on students' academic success, and it raises the level of information retention. By systematically mapping verbal and visual features of analogy concepts onto those of target concepts, analogies can facilitate elaboration, the cognitive process of building relations between what is already known and what is new (Paris & Glynn, 2004).

Another important result emerging from the study is that students were observed to create their own analogies after they were introduced analogies and the way they are used. At the end of the two-month period, there was also an increase in the number of inclusive education in-group activities.

However, during the process, students sometimes interpreted the analogies improperly. In line with this finding, some researchers and educators have expressed a concern over the use of analogies because of the potential for learners to form misconceptions or "alternative conceptions" (Donally & McDaniel, 1993; Zook, 1991; Zook & Maier, 1994). Thus, in some topics students were assisted to change their wrong analogies. In line with Paris & Glynn's (2004) findings, the results of this study, in this respect, suggest that an elaborate analogy can help learners to make correct inferences by making the similarities between the analogy and the target concept verbally and visually explicit.

To be able to avoid these drawbacks, the instructor who plans to use analogies should conduct a pilot study with the analogies to be used and identify any possible misinterpreted analogies so that they can be clarified and/or modified accordingly. It is also advised to use different analogies for the same concept, and to support these analogies with pictures, videos, figures, etc. This suggestion was stated by a student as "an analogical simulation taken from a web page to explain how dual-core processors work rose my understanding substantially." Elaborate analogies likely do these by establishing in learners a sense of self-relevancy or personal involvement (McWhaw & Abrami, 2001; Wolters, 1998). This explanation has also been supported by other students' responses in the interviews. Most of them indicated that the elaborate-analogy text was most interesting because it compared an abstract science concept to something more familiar to them. A typical comment was: "I know about photography. So it was more interesting when the eye was compared to a camera." This is a common characteristic of learners who are described by Wolters (1998) as being actively involved in the self-regulation of their learning. These learners frequently state "I think about how the material relates to my life" and "I connect the material to information that I already know" (Wolters, 1998, p.233). According to Wolters (1998), learners who are self-regulating their learning are more likely to be engaging in elaboration, critical thinking, and metacognition (Paris & Glynn, 2004).

The overall result of the study clearly maintains that detailed analogies are successful in teaching computer hardware. Therefore, it is suggested that detailed analogies be used frequently, especially while teaching hardware units, and they should be supported with pictures, videos, figures, etc.. For further studies, it is recommended to extend analogy for the learners, and to research the effects of analogies upon retainment in learning.

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