

## **An Examination of Types and Usefulness of Analogies Generated by Upper Primary School Students – A Case Study Rawatee Maharaj-Sharma**

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### **Abstract**

*The nature, type and usefulness of analogies generated by upper primary school students are discussed herein. This work looks at the range of analogies upper primary school students generate and how they use them to develop conceptual understandings. Fifty-five standard four students were asked to generate analogies during a science unit of work and to complete a Perceptions Questionnaire about the instructional utility of the analogies they generated. A number of different analogies were generated by the students and while many students indicated that analogies represented a fun and interesting way to learn science concepts, some of the students preferred the use of summaries and worked examples and suggested that these were more effective in helping them to develop scientific conceptual understandings.*

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**Key words:** Key Words: analogies in science, use of analogies, perceptions of analogies

### **Introduction and Literature**

Constructivists advocate that students are active learners who attempt to construct meaning and arrive at understandings of new situations based on their prior knowledge and experiences; either formal or informal. This construction occurs readily when students are provided with meaningful learning opportunities which allow them to generate links by relating new material they are learning to understandings derived from what they already know. The use of analogy is one strategy that can effectively bridge the gap between the known and the unknown by creating meaningful linkages between both realms.

In simple terms, an analogy is a comparison of certain similarities between things which are otherwise unlike. An analogy consists of two components: the **analogue** and the **target**. The **analogue**; the familiar situation or object; provides a model through which students can make assumptions and inferences about the unfamiliar or new situation or object, called the **target**.

Reasoning through the use of analogies can help students form concrete mental pictures of science concepts or processes as it urges them to use their own life experiences to offer possible explanations when presented with new situations. Encouraging students to generate their own analogies is not only an effective instructional strategy according to James & Scharmann (2007), but

also provides students with opportunities to explore and examine closely the ways in which the analogue and the target are similar and where they are different (Harrison & Coll, 2008). This process is critical when using analogies, as it allows students to realize where the analogies “break-down”; what aspects of the analogue cannot be wholly transferred to explain aspects of the target (Hartman & Glasglow, 2002). Identifying where an analogy breaks down, may not be an easy task for students, so it is important that meaningful guidance be provided for students throughout the process to help them to arrive at the point where they can ‘see’ where an analogy breaks-down and can understand why it breaks-down.

When, students are encouraged to develop, to present and to share the analogies they generate, teachers can gain valuable feedback about students’ learning; feedback that will expose potential misconceptions and flaws in reasoning and thinking that students may have developed (James & Scharmann, 2007). As a teaching tool, analogies can be effective in bridging the gap between students’ perceptible world and the imperceptible world of theoretical concepts. If, according to Kipnis (2005), the primary goal of science is to explain natural phenomena, which scientists achieve by generating and testing possible explanations, then there is enormous merit in using analogies to develop scientific reasoning skills among students.

Orgill & Thomas (2007) posit that when teachers use analogies to help explain concepts to students, they are better able to construct more accurate conceptions of complex ideas. They suggest further that, ideas become “more internally consistent” when analogies are used to teach science concepts. English Physicist N.R. Campbell suggests that analogies are more than mere aids to the conceptualization and that they are in fact an essential part of theory itself, without which theories would be completely ‘valueless and unworthy of the name.’ In this regard, Wong (1993) and Glynn (2007) contend that the generation of analogies helps learners to transit new experiences into familiar ones and further, that self-generated analogies stimulate students’ inferences and insight, thereby helping them to control the generative capacity of their own analogies to advance their understanding of conceptually abstract phenomena.

Despite the many benefits that can be derived from using analogies in science teaching, Harrison & Cool (2008), also cautions that when using analogies to teach science concepts and processes, teachers must be careful to point out, to students, those aspects or areas in which the analogue and the target are different; in other words; those “places” where the analogy itself breaks-down. Brown and Salter (2010), too, suggest that it is extremely important that due caution be exercised to be sure that students remember the content and not just

the analogy. As Else, Clement & Rae-Ramirez (2008) emphasize, this is critical to ensure that upon exiting the learning experience, students realize that the analogy is only an aid to understanding a concept or process and is not in fact the concept, process or principle itself.

A number of research studies speak to the many cognitive and affective benefits of using analogies to teach science lessons (Glynn (1996); Paris & Glynn (2004) and Kipnis (2005)), but there is very little research on students' ability to generate their own analogies. Among those that focus on the generation of analogies (Duit & Treagust, 2003), most explore the phenomenon at the secondary and in some cases the tertiary levels (Harrison & Treagust, 1994). Very little is known about the use of analogies as a teaching/learning tool at the primary school level and even less is known about students' ability to generate analogies, and the kinds of analogies students generate at this level.

This study therefore sets out to investigate the types and usefulness of analogies generated by standard 4 students (average age 10) and their perceptions of the instructional utility of these analogies. The following research question guided the approach adopted in this work:

*What types of analogies can 10-year-old science students generate and how useful do they perceive them to be for science learning?*

### **Methodology**

Participants in this study consisted of 55 students (26 males and 28 females) from a standard 4 class in a government primary school in south Trinidad. The title of the science unit during which the study took place was *electricity*. The unit consisted of two sections a) basic circuitry and b) effects of electricity. This was part of the normal course of work the teacher taught to the class so that no special provisions were made for the purposes of this study. Prior to initiating the study, all the participating students were exposed to three 30-minute training sessions on the generation of analogies. During these sessions they were exposed to methods of generating analogies through the use of an analogy generation worksheet (Middleton, 1991) and they were also presented with opportunity to generate their own analogies for various science topics based on their prior experiences, knowledge and understandings. They were also encouraged to present the analogies to their peers for review and critique. As advised by Bulgren, Deshler and Schumaker (2000), the class teacher took a leading role in reviewing and commenting on the suitability of the analogies and the extent to which they were relevant and practical in the various situations the students chose. Special emphasis was also placed, during these sessions, on pointing out to students those places where the particular

analogies broke-down and students engaged in discussions about this aspect of using analogies. Throughout the sessions, students received extensive feedback from the teacher in terms of the clarity and content suitability of the analogies they generated.

One week after the training sessions the unit of work was taught to the students. The unit consisted of six 40-minute lessons. At the end of each class, students were given 15 minutes to generate an analogy for some aspect of what was taught in the lesson. Students worked independently to generate the analogies and these were recorded in a tabular worksheet designed specifically for this purpose (Figure I).

Figure 1: Analogy generation worksheet

New science concept/idea (Target)	Everyday/common term/idea (Analogue)	Explanation of the analogy	Diagram (if needed)

At the end of each class session the analogy generation worksheets were collected and reviewed by the class teacher and the researcher and subsequently returned to the students before they left the classroom. The students were encouraged to engage in individual filing of these analogy generation worksheets. They were asked to keep a file in which the worksheets for each class session would be securely stored as part of each student’s record keeping process.

At the end of the unit of work the students were asked to complete a Perceptions Questionnaire consisting of four open-ended questions aimed at gauging their perceptions of the instructional effectiveness and utility of analogies. In this questionnaire they were asked to comment explicitly on what they liked about the analogy generation exercise, what was helpful to them and the extent to which the exercise aided in their understanding of the topic? They were also asked to comment on whether or not they would like it if their class teacher used analogies more often in the classroom.

**Data Analysis**

The analogies generated by the students and represented on their analogy generation worksheets, were analyzed to determine, in general, the various types of analogies that were generated and further which type(s) were most frequent. From the range of analogies generated, it was possible to establish

three groups based on the nature (and the accompanying explanations) of the analogies – analogue and target. These were:

Process-type analogies

Structure-type analogies

Metaphoric-type analogies.

**Process-type** analogies included those that compared scientific terms to actions or processes that students met in everyday life. For example, the comparison of the heart to a pump was interpreted as an analogy in this group as the pushing action of a pumping heart was likened to the pushing action of an electrically driven water pump.

**Structure-type** analogies included those that compared a scientific term with common everyday objects or structures that looked like or had the same physical properties as the scientific term. For example blood circulation in the human body compared to a subway system would be an analogy in this category.

**Metaphoric-type** analogies included those that compared two things in which it is initially difficult to see any similarity but which upon careful consideration reveals elements of similarities, for example the comparison of the human eye to a trampoline in which the elastic behavior of the trampoline is likened to the elastic nature of the suspensory ligaments in the eye.

### **The Categorization Process - Standardization**

#### Arriving at Consensus

Categorization of the analogies was carried out by the researcher and 3 other research assistants, all of whom are physics teachers involved in the teaching of electricity. During the standardization, analogy generation worksheets completed by ten randomly chosen students were selected and these were collectively reviewed and categorized by the four individuals to arrive at consensus in terms of the criteria used for categorizing the analogies and the context in which the analogies were generated [by the students].

#### Categorization

After this phase, the remaining analogies were randomly grouped into four batches and a batch each was assigned to the researcher and to the three research assistants. Each batch was independently analyzed and categorized (based on the criteria established in the consensus phase of the categorization process) by the individual to whom the batch was assigned. This was

important to validate the categorization process and also to enhance its reliability. It allowed for reduced subjectivity and strengthened the objectivity of the process by allowing the criteria only, and not collaborative comfort, among the four individuals, to guide the process. From this phase a list for each batch was prepared by the individual who did the analysis. The lists contained groupings of the type of analogy and the frequency with which they occurred.

After the individual categorizations were completed and the lists from all the researchers were compared, there was a 92% agreement among the lists. At the end of this phase, all four researchers met to deliberate on the 8% of analogies that were categorized differently among them. They discussed these to resolve difference among them until they eventually arrived at consensus on all the analogies generated.

#### The Perceptions Questionnaire

Four open-ended questions were used on the Perceptions Questionnaire to gauge students' perceptions about the usefulness of the analogies generated. The questions were:

1. What did you like about generating the analogies?
2. What, in the analogy generating process, was most helpful to you?
3. Did the analogies help you to understand science better? Explain why.
4. Would you like your teacher to use analogies more often in the class? Explain why.

Many students in this class were very high academic achievers and they had no difficulties understanding the questions on the Perceptions Questionnaire. [The questionnaire was piloted before being administered to the students.]. Their responses for the most parts were short sentences or phrases. These were coded and qualitatively analyzed to reveal students' perceptions about the usefulness of the analogies to them.

An interesting occurrence which was revealed in the data analysis process was that in explaining why (for their initial response to question 4 on the Perceptions Questionnaire) some students who responded in the negative went into details, using the opportunity to suggest other strategies they would have preferred instead of analogies. These responses too were noted, coded and analyzed in the context of students' general perceptions of the usefulness of analogies.

## **Results**

The results are presented in two sections. The first section presents the results of analyzing students' analogies to reveal the different types of analogies students generated while the second section presents the results of analyzing students' responses to the Perceptions questionnaire.

### Types of students' analogies

A total of 321 different analogies were generated among the 55 students over the six lessons. They spanned across the three types with the most generated in the process-type category and the least in the metaphoric-type category. Among the large number of analogies generated in the process-type category, many of them explained the idea of electric flow and resistance by making links to examples of water flow and hydro-pumping systems.

In one of the introductory lessons the concept of moving/flowing charges was explored to help students understand the process involved in the generation of an electric current. One example of an analogy generated by at least three different students for this concept was "Electricity flowing through a wire is similar to water flowing through a pipe. Larger pipes allow more water to flow just like thicker wires allow more electricity to flow." This was categorized as an example of a process-type analogy.

*[It is important to realize that electricity flowing through a wire does not share surface/physical similarities with water flowing through a pipe. Electricity is not wet and does not splash. However, electricity flowing through a wire is similar to water flowing through a pipe in the sense that larger pipes allow more water to flow and larger wires allow more electricity to flow].*

Another analogy in this category generated by the students was the idea of batteries "pushing" electricity through a closed circuit just as pumps "pushes" water through a closed piping system. In this case the analogy is being made of the pushing process.

The idea of a complete circuit was made analogous to a big loop of rope by two students. This again was categorized as a process-type analogy in which the students likened one person to the battery who pulls the loop through his hands. Another person is the resistance and squeezes the rope. Friction with the hands of the resistor person means they can feel the energy transferred as heat. In this case the ideas of both a complete pathway for flowing charges as well as the heating effect of an electric current were explored in the analogy.

An example of one structure-type analogy generated by students was the obstacle course to explain alternative pathways for electric flow in parallel circuits. Students drew obstacles courses with several different routes to get

from start to end and likened the obstacles along the paths to switches which if opened prevented the traveler from getting through, thereby forcing him to seek an alternative path that allowed for him to get to the end.

Examples of metaphoric-type analogies were quite few; one example was the comparison between a broken bridge on the road to an open switch in a series circuit. The student explained that if the bridge is broken and this is the only pathway to get from one destination to the next the journey remains incomplete until the bridge is repaired (analogous the closing the switch).

The number of analogies generated in each category can be summarized as follows:

<u>Category</u>	<u>No. of Analogies</u>	<u>% of the Total no. of Analogies</u>
Process	183	57%
Structure	123	38%
Metamorphic	15	5%
<b>Total</b>	<b>321</b>	<b>100%</b>

It is important to note that in the Process category some of the analogies were very similar in terms of the analogy itself and the content/idea/object to which it was compared, but because the students generated the analogies independently the explanations they provided in each case was sufficiently different to warrant acceptance of the analogy as a unique one in several instances.

#### Students' perception of the usefulness of the analogies

Response from the Perceptions Questionnaire revealed that students generally enjoyed generating the analogies and comparing their analogies with those generated by their friends. In particular they seem to like "coming up with things that were similar to what was shown in class." They seemed to have liked also the process because it allowed them to work collaboratively with their peers. A few students however suggested that the process was a "challenging" one for them as they had to "think long and hard" before they came up with an analogy. The students agreed that the analogies enabled them to better understand the electricity concepts, but were divided; almost equally; in response to their view of whether analogies should be used more often in classroom teaching.

Analysis of the Perception Questionnaire revealed the following:

1. 72% of the students liked engaging in the analogy-generation exercise
2. 68% of the students felt that the exercise was helpful to them
3. 93% of the students indicated that the exercised aided their understanding of the topic

4. 52% of the students would like to have the analogy-generating exercise repeated in other science topics
5. 10% of the students said they would prefer the use of worked examples
6. 10% of the students suggested that summaries might have been more useful to them.

Examples of actual verbatim obtained from the students as revealed from the perceptions Questionnaire are presented below:

What did you like about generating the analogies?

*S1: "...it was nice to work with my friends...I could think of something I know about to explain the electricity..."*

*S2: "I liked explaining my analogy to my friend..."*

*S3: "I looked for how my analogy was similar to my friend's..."*

*S4: "I liked coming up with the analogy....but didn't like presenting it...."*

What, in the analogy generating process, was most helpful to you?

*S1: "...seeing how similar electricity was to other things...."*

*S2: "doing the analogies helped me to think carefully about what was happening."*

*S3: "....It helped me to look at things in a different way...."*

Did the analogies help you to understand science better? Explain.

*S1: "yes .... I was able to understand resistance very well"*

*S2: "yes ....parallel and series circuits are very easy for me now..."*

*S3: "yes, with the heat I felt on my hand I will never forget about the heating caused by a current"*

*S4: "yes.... I understood all the lessons...."*

*S5: ".... I feel like I understand electricity very well.... I can explain current and resistance to somebody now...."*

*S6: "I understood a lot about electricity.... It was very interesting...."*

Would you like your teacher to use analogies more often in the class? Explain.

*S1: "yes, I might understand the other topics just as good...."*

*S2: "no, it takes too long to think about the analogies and come up with them and them to have to explain it is sometimes hard"*

*S3: "no, I prefer reading the notes and learning from worked examples...."*

*S4: "yes, the analogies made the topic fun.... I was able to see how it was similar to other things besides electricity..."*

*S5: "... summaries and worked examples would have been better..."*

## **Discussion**

Textbooks and teachers often use analogies to help familiarize students with concepts that are abstract and outside or new to their previous experience. It has been argued that analogies motivate students to learn by provoking their interest and that the discussions that occur when using analogies not only help students construct their own knowledge, but also assist teachers in basing instruction on students' prior knowledge and existing alternative ideas/conceptions. Having students generate their own analogies has the added benefit of encouraging students to assume some ownership for their learning, so that they recognize that teachers alone do not carry the responsibility for classroom learning.

In this work, the number of analogies generated by the students was surprising, which seems to suggest that this group of students may have a well-developed ability to formulate links between prior knowledge and new information. Analysis of the types of analogies generated by the students provided valuable insights into the kinds of links that students make between prior and new knowledge. The category in which the highest percentage of analogies was generated; (process-type analogies – 48%); compared processes from students' daily lives with new processes they were learning about. Kipnis (2005) suggests that the generation of this type of analogy indicates that it is easy for students to associate actions and processes with which they are familiar; those that they may have used, witnessed or interacted with themselves; to similar kinds that they meet in formal classroom instruction, even for the first time. According to Harrison & Coll (2008) and Else (2003), this is reflective of mental processing at high cognitive levels; levels as high as synthesis. The fact that most of the analogies generated were in this category suggests that students do in fact come into the classroom with a broad range of experiences and this suggestion forces us to now examine the extent to which teachers draw from this reservoir to achieve meaningful learning in their classrooms.

The category in which the least analogies was generated; (metaphor-type analogies); compared a science concept with something that was "unexpectedly" similar. In these analogies the analogue and the target are totally different in all respects except one. This according to Glynn (2007) suggests that students often have difficulties seeing links between or among things that do not have an obvious similarity or several obvious similarities. The process of generating metaphoric-type analogies is not an easy one and as Glynn (2007) have revealed, there is an element of "mental abstractness" that students must possess to do this effectively. This Glynn says is more common among older students and while there is no convincing data to suggest why

this might be so, he suggests that it may be linked to higher levels of physical and mental maturity.

The generation of structure-type analogies; like process-type analogies; is directly related to the prior experiences, knowledge and interactions that students have and the extent to which they can effectively transfer and link these to formal science learning. Orgill & Thomas (2007) have indicated that the contexts from which students come seem to have an impact on the kind of analogies they generate; particularly in the case of the generation of structure-type analogies. Based on the participants in this work; this seems to be the case, but indeed this perception warrants further investigation.

The findings of this work clearly have important instructional implications for the ways that and the frequency with which teachers adopt strategies that allow for the integration of students' everyday experiences into their classroom experiences. Allowing students to generate analogies allows teachers to 'see' where students are coming from and gives teachers an opportunity to gauge the levels of mental processing that students engage in. As a result teachers can identify almost instantly, any areas related to scientific processes, conceptualization or structure for which students may have misconceptions or alternative ideas. As articulated by James and Scharmann (2007), and seen herein, while having students create their own analogies is an effective instructional strategy, teachers must analyze their students' analogies carefully to determine exactly what sense of the world their students are making. Identifying where an analogy breaks down may not always be an easy task for students and so it is critical that meaningful guidance be provided for students throughout the process to arrive at the point where they can 'see' where an analogy breaks down and can understand why it breaks down. This work shows that analogies aid in students' understanding and when students generate their own analogies this understanding is further enhanced, allowing for sustained retention of new material learnt.

The above having been said, it is important to note that not all the students engaged in this work found favour with the analogy generation intervention. A few indicated that even though they recognized some value of the intervention, that they preferred the traditional direct-instruction methods with which they were familiar.

Even with this view in mind, this work revealed that, in general, analogy generation is a fun learning activity and if it is well structured can promote collaboration and discussion among students. It is an effective way to encourage students to learn from each other and to appreciate that the same concept, idea or process can be represented in different ways but with equal meaning and value.

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