The Rock Cycle - a complex object of learning

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ABSTRACT

In this article a learning study is presented, and the object of learning is sedimentary rocks' formation and decomposition, a part of the rock-cycle. The study included 5 lessons in 5 different groups of 5th grade pupils. 85 students and 7 teachers participated in the study. The lessons were 40 minutes each and the teacher and location of all classes remained constant. 4 lessons were planned based on variation theory, while one lesson served as control. The results show that the way the teacher presents the aspects of the object of learning has a great impact on the pupils' learning outcome. The contrast between the rock-cycle and the water-cycle made the results increase, but the contrast between the rock-cycle and the organic cycle did not affect the learning outcome in a positive way. As the pupils had an understanding about the water-cycle, this understanding seems to help them understand the rock-cycle, a kind of transfer from a known phenomenon to an unknown phenomenon. .

Keywords: variation theory, learning study. Complex object of learning, rock- cycle, sedimentary rocks' formation and decomposition

1. INTRODUCTION

This study focuses on how a complex object of learning can be defined and how its aspects can be offered for pupils' discernment by the use of variation and simultaneity. To exemplify a complex object of learning we have chosen the example of the rock cycle because the knowledge has to be a kind of system instead of finding one or a limited number of correct answers. Even if the study is conducted in a face-to-face learning situation, the examples can be used in virtual educational settings. In order to understand our environment and how the earth is constituted, a holistic approach and system thinking are required. One of the keys to understanding the world around us is to know and understand the formative processes of our landscape. Since the various forming concepts of our landscape and their processes are part of a larger system of the rock cycle (in which the different processes affect each another), system thinking is an important element for understanding the formative processes of the landscape holistically. To understand the cycle it is very important to be able to discern and understand the different concepts, relationships and processes of the rock cycle. This study aims to describe what it takes to learn a system instead of single phenomenon (on a more or less detailed level), and ask whether the assumptions made in previous studies [1, 2, 3, 4] are also valid when complex objects of learning are focused upon.

The object of learning is the sedimentary rocks' formation and decomposition, i.e. a part of the rock cycle (Figure 1) [14,15,16]. From now on, the object of learning in this study is defined as this particular part of the rock cycle. The rock cycle is a complex object of learning, since it includes many different kinds of concepts and relationships. System thinking is defined as having the ability to identify a system's components and see the connections between them and the aspects of the whole system [10]. The teaching of geology is based on system thinking, in which a variety of perspectives are highlighted at different times, in changed contexts and with different purposes. It is also possible to see the system as different "levels of performance" [12], i.e. levels that describe/explain a system of many

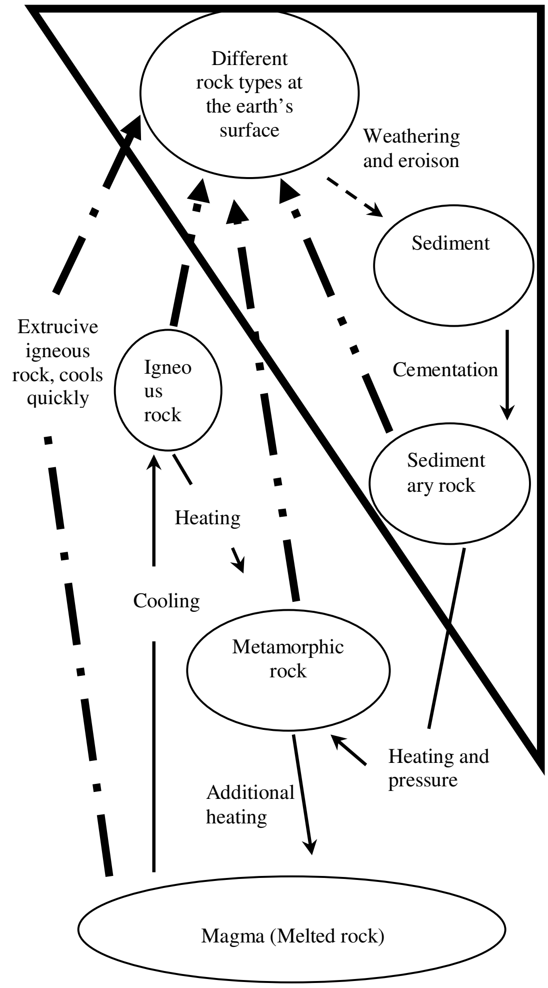

Figure 1 The rock cycle and the learned object (marked with a triangle

interacting entities/concepts. To understand how the whole system works, the student has to understand all levels and the connections between them. The results of a study about the global carbon cycle [10] showed that students find it difficult to see the cyclical processes (cycles). Instead, students use a sort of linear process. In this case the earth is seen as an inexhaustible resource for coal and the atmosphere is seen as an unlimited drain on coal. Students also show difficulties in seeing the systems' constant changes, as these are only observable in a historical perspective. Researchers [10] argue that the lack of models in schools makes it difficult for students to acquire "level-thinking". The computer is a useful tool to illustrate systems, and it is available at most schools. There have been several studies in which students have to use computers to simulate various systems (simple ecosystems, the movements of particles of gas) through various programs. That allows students to enter the system (program) and change the criteria to see how that affects the system; students can thus obtain "level-thinking".

> ”… that understanding the reciprocal relationships within and between each of these systems in necessary for informed decision making concerning environmental issues." (Kali, Orion, Eylon, 2003, p. 545)

Using a systems approach is considered to be an important ability in technology and science, as well as in everyday life [11]. And to predict the consequences of alternative decisions in environmental issues, it is important to consider the relationships between the various systems. In one study specifically on systems thinking in a scientific context, the point of departure in an educational situation was the rock cycle [11]. Respondents were children in junior high school. After a lesson based on the customary pedagogical practices, the students took a test. The results clearly showed that students generally lacked a broader systems approach. After that, they were asked to work with activities that integrated different subjects, and the teacher was more a supervisor than a lecturer. The results of the test taken after this activity showed a marked increase in systemic thinking.

Kali et al.'s [11] results showed that students rarely integrate parts into a whole by themselves. It is therefore important that the teacher plan and implement activities in which this occurs. The aim is to get students to work on a task following the lesson, and feel enticed/forced to reflection. In this way, students can connect their experiences to a context. But we do not see the role of the teacher changing from a lecturer to a supervisor as the important variable. We have used the same method, but different ways of designing how the content of the object of learning is organized.

> "Why can we not study ecology indoors and transfer the knowledge to the authentic world out-of-doors. According to transfer studies and variation theory there have to be certain basic similarities between the situations for transfer to be possible." p.54 "As I have noted earlier the key is not the outdoor context itself and it does not have to be the larger part of instruction but they have to be well planned and executed… Instructions for reading nature must include field work but it is not necessary to conduct all teaching outdoors… As I see it we need to help the future teachers to know how to look, what to discern in nature but also help them to link what they see to some models of ecosystems functioning. "p.65 [13]

2. THEORETICAL ASSUMPTIONS

One previous study about complex objects of learning has been carried out within the research project "The Pedagogy of Learning" funded by the Swedish Research Council. In this study the object of learning was historical awareness, which can be seen as a kind of ability [5]. All studies included in the research project are based on the same theoretical concept, variation theory [6, 7]. Each individual study aims, on a general level, to test the theory in different circumstances to see if its assumptions are valid. The assumptions are that variation is needed to discern aspects of an object of learning that are critical for learning. Presenting the aspects to the students via variation both of single aspects and several aspects simultaneously makes it possible to discern the object's aspects. However, the student also has a kind of individual dimension of variation through discerning the aspects in relation to her or his previous knowledge or experiences. Hence the design of instruction or information on a web site is crucial for what learning is possible, as the teacher has to take into consideration both the object of learning and the students' previous understanding.

Variation theory is based on the concepts discernment, simultaneity and variation. However, the variation is not about methods, but how the different aspects of an object of learning are offered the students in a learning situation. Thus when we teach about the rock cycle we can choose different aspects to present. Such aspects can be the influence water has on the process of turning stones into sand, what soil consists of (whether it is minerals or organic material) and so on. When teaching about a complex object of learning there are several choices to make when deciding what to offer the students (what can be discerned), what is offered simultaneously and how to vary the aspects of the object of learning. By analysing what happens in the learning situation, the results show what seems to be powerful and what seems to be irrelevant according to the students' learning outcomes.

3. METHOD

The method used is learning study with semi-parallel lessons [2, 3, 8]. Learning study is a hybrid of lesson study from Japan and design experiment. It is a kind of action research [9] at school done in cooperation between teachers and researchers. In this study the lessons are conducted in two cycles, with two parallel lessons in each cycle. The design of the first lessons (A1 and A2) was based on interviews and screenings. The remaining two parallel lessons' (B1 and B2) design was based on the analysis of the lessons and learning outcomes in the previous parallel lessons (A1 and A2). This means there are four lessons in the learning study. In addition, two control lessons (C 1 and C2) have been conducted. However, one of the teachers misunderstood the researcher's instruction and taught the students the content before the research lessons. Hence we had to exclude the data from this lesson (C2) from the result.

The study was conducted in 2009 in Sweden, and included 6 lessons in 6 different groups of 5th grade pupils. A total of 109 students and 8 teachers participated in the study. As one group (C2) was excluded (see above), 85 students and 7 teachers remain. For practical reasons, the selection of students was from schools in the neighbourhood. The lessons were 40 minutes each and the location of all classes remained constant. 4 lessons were planned based on variation theory, while two lessons served as controls. Since the location was an important component of the study, a sandy beach in Åhus (Sweden) with a beach view was selected.

To examine the pre-understanding and experience of the object of learning, the study started with interviews with 6 students. After that, a screening was carried out including 37 students, aiming to find the critical aspects of the object of learning, or what it takes to learn the chosen content. The lessons' design was planned based on the results of the interviews and the screening. Since the lessons were carried out on three different days (two lessons on each occasion), lessons 1 and 2 were given first, and after an analysis lessons 3 and 4 were planned, designed and implemented. The empirical data were collected through written tests and video recordings. Each pupil took the same test before the lesson, directly afterwards, and with a delay of 4-5 weeks. The test consisted of one question, namely: "Draw and/or write what sand is, what it has been and what it can be in the future, and what happens when it changes". The four experimental classes were carried out with the same content and methods, but the aspects of the object of learning were presented a bit differently.

Data

The qualitative data material from the tests are converted to a quantitative measurement. If the student responded fully to the question in the test, the student could get 16 points. Each point corresponds to a particular concept/process of the response that is relevant to the issue. The concepts/processes must be used in the right context, to receive one point for each concept/process.

The concept of weathering:	
Water (rain, waves)	1
Wind	2
Ice (frost shattering)	3
Glacier	4
Rock against rock	5
The concept of erosion:	
Transport (water, wind, ice)	6
Soil (org. material-stone, sand, clay)	7
Sorting	8
The concept of cementation:	
Sediment (layer on layer)	9
Pressure	10
Heat	11
The concept of circulation:	
Cycle/circulation/round and round again	12
The concept of size (shape):	
Mountain	13
Stone	14
Sand	15
Clay	16

Lesson A1

The discussion of the lesson was based on pictures representing different concepts in the rock cycle. The pictures were presented one by one, structured in a sequence starting with a mountain. The second level was weathering and erosion, and this was represented by rain, wind, ice (frost shattering) and watercourses. The third level showed the shapes of the material after weathering. The fourth level showed the erosion, the transportation of the materials and how mineral and organic materials are mixed and sorted during the transportation. The last level, the fifth, was the concepts of sedimentation and cementation (Fig.2). The unvaried aspect in the first lesson was the cycle presented to the students, but presented linearly (not cyclically). The varied aspects were the representations of the weathering and erosion and the different shapes the material may appear in.

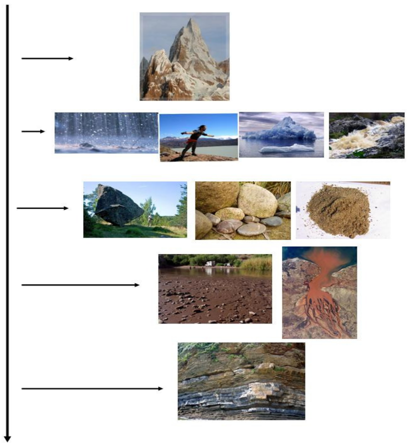

Figure 2 The rock cycle (linear, pictures presented one at a time)

Lesson A2

The difference between the first (A1) and the second (A2) lessons in the semi-parallel learning study was essentially the structure and the use of contrast. The structure was changed from a sequence to a simultaneous presentation of the rock cycle and the organic and water cycles. All three cycles were presented in circles and not, as in lesson A1, in a linear structure. All cycles were visible immediately at the start of the lesson (Fig.3). The varied aspects in the second lesson (A2) were the same as in lesson A1 concerning the rock cycle. However, this time the cycle was also represented as a visual cycle. Another varied aspect was the three different cycles — the rock, organic and water cycles (Fig. 2), presented at the same time (simultaneously). The invariant aspect was how the three different cycles were presented.

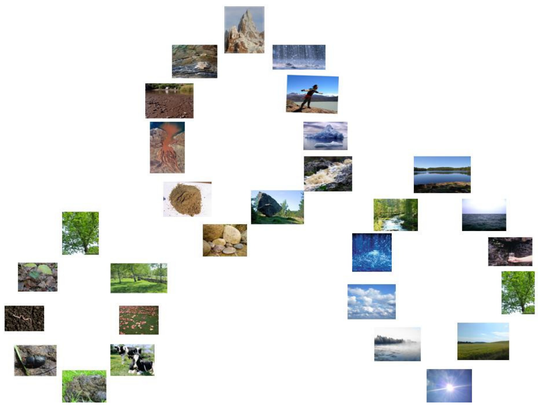

Figure 3 The three cycles together (rock cycle, organic cycle and water cycle)

Lesson B1

The results of the first two lessons (A1 and A2) were analysed, and the remaining difficulties were discussed before lessons B1 and B2 were designed. We found that the students did not discern the difference between organic and mineral material. They could not differentiate between clay and soil, which shows they confuse the organic and rock cycles. On the other hand, they did not seem to find the water cycle problematic. Hence we decided to focus on only two cycles in the two remaining lessons, the rock and organic cycles. The pictures of the rock cycle were presented, as well as the organic cycle as a contrast. In the lesson the teacher made a more explicit clarification of the difference between clay and soil.

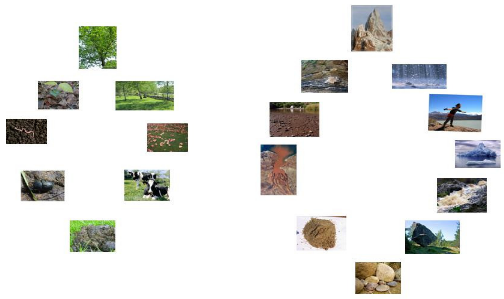

Figure 4 Two cycles together (Rock cycle and organic cycle)

Lesson B2

The lesson was based on the pictures below (Figure 5), showing the rock cycle and the organic cycle simultaneously, as contrasts. A clarification was made of the difference in clay and soil. The term *mineral* was introduced to show that rock, sand and clay are the same material but in different representations (Figure 6).

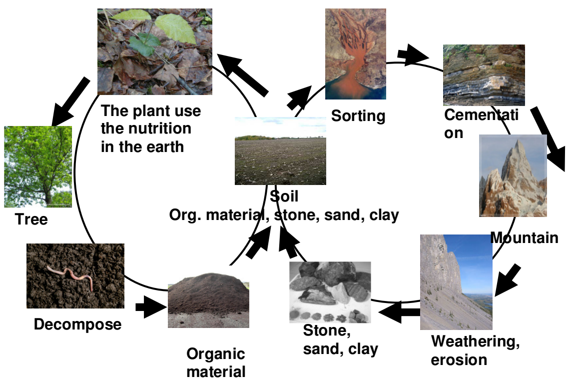

Figure 5 The rock cycle's relationship to the organic cycle

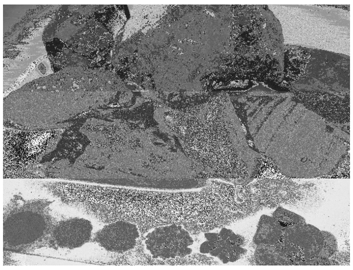

Figure 6 Minerals in different sizes and shapes

4. RESULTS

The results show that the concepts on which variation theory is based are also true for learning involving complex objects of learning. The results also support previous findings that the lowest achievers gain most when they are offered instruction based on variation theory. Different forms of contrasts were used to develop the pupils' knowledge, which was powerful, and the results could be explained by the instruction offered during the lessons. The results were analysed both on an individual level and a group level and are described in Table 1.

Table 1. Mean scores in the six different groups.

Group/Lesson	Pre	Post	D Post
A1	2,55	4,65	4,10
A2	2,44	5,13	4,63
B1	2,53	5,12	4,35
B2	2,71	4,79	4,43
C1	1,69	3,15	2,92

The different outcomes also show that the environment is not crucial for the learning result, as all six groups were located at the same area during the lessons. The same teacher taught four of the groups, so the teacher is also an independent variable. However, the analysis of the learning outcome in combination with the analysis of the video recordings show how differences in what aspects are offered in the learning situation affect the learning outcome.

First of all, the four research classes developed more than the control group. And, in line with previous studies, the group with the lowest result (A2) is the one of the research groups that gained most. However, the control group had in fact the lowest result on the pre-test but developed less than the classes in the research groups. The concept of circulation (12) increased from seven in lesson A1 to 14 in the lesson A2. Lesson (A1) presented a linear rock cycle, and pictures of the concepts were presented one at a time. In lesson A2 two contrasting cycles were used. This was done by using a contrast to the rock, water and organic cycles, which are familiar to the students. The results point out that if the learner sees the similarities between the rock cycle and the water cycle, that the process is the same (cyclic) as well as the differences between the concepts they are composed of, the learning situation seems to be more powerful. The water cycle seem to be the cycle that had most impact on the students' learning outcome, as the groups that got the organic cycle instead did not develop as much.

The excerpt below, from lesson A2, shows how important the teacher's way of offering the students the object of learning is for their learning outcome:

T: Then there is what is the smallest, almost like, what it is almost like?
S: Powder.
T: Yes, powder, or like…?
S: Dust.
T: Yes, dust, almost.
T: Flour, almost, it feels like. And what is it, then?
S: But we can not try to take this kind of sand here?
T: Yes, that kind of sand.
S: Like this?
T: Yes, let's see. I'll take this little powder into my hand, then we put some water on it. Now, let's see what happens.
[The teacher puts water on the powder he has in his hand.]
S: Quag! It just becomes clay!
T: It becomes clay, I have to take a little bit more.
S: You take powder.
T: Yes, I take powder. What is it now? Feel it!
S: Like a kind of cement.
T: Or like…? Does it become soil, or what is it now? Almost like cement.
S: That was what I said!
T: Yes, but it is not. Can anyone of you find out what it is?
T: What is it? It is possible to roll it up.
S: I know! A kind of dough.
T: What did you say? Someone said something..?
S: Ceramic or clay
T: Clay! That's exactly what it is! It's clay! That is what is the finest of sand, or of the mountain. So it is clay, the finest parts. It's the clay, which once has actually been rock.

In the post-test of the second lesson (A2), we find student replies like: "To get clay you have to mix it with water." "It rains on the sand so it will be clay." "There will be clay with the aid of water." Students have misunderstood what clay is, thanks to the way the teacher presents the phenomenon as if it is water mixed with sand, which become clay. In lesson B1, the teacher presents clay like this:

T: And then there is another one which is almost like a very white powder.
S: Like dust.
T: Like dust, yes.
T: What can it be, then? What is it that have smaller size than sand, do you think?
S: Dust.
T: Anyone who can guess?
S: Dust.
T: Dust? This is actually clay.
S: What?

T: Yes, it is clay.

T: Maybe not in the way you recognize it, as it is dry, but if we now pouring in some water…

[The teacher pours some water on the clay particles.]

T: ... you may recognize it better,

[The teacher mixes clay with water, takes more clay from the students' sieve.]

T: If I can borrow some of yours, too.

T: Let's see if we can do a little clay here. If you feel there now, or look at it, feel with your hand. [The students touch the clay.]

T: Do you feel it? Do you recognize the clay now? Right? I'll come to you too. .

T: Back, back, I'll come to you. Here you can see it is clay.

S: Mm.

T: Mm. Can you see it is clay? Or, it was in fact clay before, but you recognize it again when it gets wet, right?

S: Yes.

T: Mm. So clay is the material that is the very smallest.

In this group, most of the students did not claim that clay is sand mixed with water. The differences in the way the teacher offers the students to understand what clay is are important for their understanding. The missed important information that clay is clay even if there is no water was not given in lesson A2.

Figure 7 One girl suddenly turns around with sand in her hands and says "so this sand has been stone before!"

5. DISCUSSION

The results of this study show many interesting things. As it was the same person teaching all targeted groups (A1, A2, B1 and B2) and the same environment (outdoor classes) those variables are invariant and the differences in learning outcomes cannot be caused due to these variables. And even if the control group (C) was taught by another teacher, who did not teach based on variation theory, the learning environment was the same.

Instead, the differences we can see that have implications on the students' results are the way the teacher organizes and presents the object of learning as what it actually is and what it is not. To do so, contrasts with other cycles were used, and the contrast with water seems to have been most powerful. Also the sharpness in the verbal presentation was important, e.g. to understand that clay is the smallest particles and not only clay if it is mixed with water.

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