Metacognitive use of biological knowledge in Elementary School

Silvia Caravita*

SUMMARY

This study is ground on the assumption that children not only appropriate content knowledge in school but internalize a model of how knowledge is queried and built. The instructional setting communicates this model even without deliberate intervention. We have carried out an investigation by submitting a written questionnaire to the pupils of a small sample of 4th and 5th grade classes that were characterized by different learning environments: traditional, inquiry oriented, inquiry and communication oriented. We focus here on children's performance in a thought experiment that was included in the questionnaire. The task consisted in predicting the kind of information about an unknown animal that different sources of information (long-term vs short-term observation, books, local people) can possibly provide.

Notwithstanding the limited differences of competence in biological content among the pupils, differences emerged in the ability to regulate predictions or to adjust them when switching to another procedure or source of inquiry. Children of non-traditional classes seemed to be more aware that new biological features can be discovered when changing the source. Our results show how the pedagogical approach can affect children's ability to use their knowledge of biological facts in a reflective way.

KEY-WORDS: metalearning, biological education, elementary school

* Istituto di Psicologia CNR, V.le Karl Marx 15. 00137- Roma, Italia.
e-mail: caravita@ip.rm.cnr.it

INTRODUCTION

The term "metacognition" means different things to researchers working in different subareas of cognitive and developmental psychology (Cornoldi, 1995). The great majority of the studies is concerned with with general abilities related with students's perception of knowledge acquisition and with intentional learning, less investigations have been done about application in specific disciplines (Rowher and Thomas, 1989). Learning in a subject does not imply only mastering content but acquiring the thinking tools that are necessary for using knowledge in a purposeful way, to predict and select information in relationship with the conditions of inquiry.

From 10 years of age on, children show a growing ability to utilize strategies, to make use of external feedbacks for adjusting their strategies, a tendency to transfer them to new contexts and to coordinate strategies with knowledge (Schneider and Pressley, 1989; Perkins and Grotzer,1997; Borkowski, 1996).

The instructional variable plays a very relevant role in this respct but, as Cornoldi claims in his book, we are convinced that education to reflection does not identify with metacognitive training, i.e. a de-contextualized acquisition of specific strategies that are aimed at fostering awareness and self-monitoring. Metacognitive growth should rather result from a global approach to teaching/learning which focuses students on the processes while they are occurring, which calls attention on divergent strategies that have emerged from different situations and on the relationships between processes and outcomes, .

The transmissive pedagogical approach mainly based on books reading has been widely criticized and is not expected to produce a constructivist view of knowing in the students, but also the discovery learning approach that teachers practice in reaction to the more traditional way may not be an effective alternative either, if the emphasis is placed only on the empirical experience. Besides being actively engaged in manipulation, in confronting their ideas with reality, pupils must be involved in the intellectual component of the inquiry, in the re-elaboration of their experience. Collaborative work, communication among groups to exchange information, comments, ideas are considered as potentially powerful conditions to motivate and enhance reflection on actions and procedures. Innovative projects ground on socio-cognitive theoretical perspectives enrich the class with these kind of opportunities. In our study we have taken into account these different types of educational environments to find some evidence of the consequences that they may have on children's representation of inquiry procedures used to go beyond the given knowledge, in particular knowledge related with biological facts.

We must make clear that our preliminary study probed children's ability to use metacognitively their knowledge in a thought experiment and not in an actual situation of application. It therefore deals with declarative and static metacognitive knowledge, in Pintrich et alt. terms (1999). We have gathered data from other questions included in the questionnaire and from observations carried on in some of the classes included in this sample, but these findings will not be included in this short preliminary report.

EMPIRICAL PROCEDURE

The sample included three fourth grade and three fifth grade classes of five different elementary schools of Rome. The socio-economic variable was balanced across the sample.

Three educational approaches were represented by each couple of fourth and fifth grade classes: traditional approach (T), characterized by discovery learning (DISC), comunication oriented approach (COM).

The distinguishing features of these learning environments can be summarized as follows:

Traditional classes

National syllabus :	main reference for the identification of content topics
Children prior knowledge:	under-estimated and not used as a ground for planning
Communication :	teacher-centered
Work organization:	mainly individual
Text books:	privileged sources
Practical experience:	very limited and fragmentary; some guided experiments or demonstrations
Field-trips:	sporadic and non-explorative
Products:	narrative reports on note-books

Discovery Learning classes

National syllabus :	loose reference for the identification of objectives and broad themes
Children prior knowledge:	constant source for on-line adjustements of the curricular planning
Communication :	teacher mediates peer interaction
Work organization:	individual and group-work
Text books:	one source among many others
Practical experience:	constant component of the class, in- and out-door, to build the ground for discussion and reflection
Field-trips:	explorative and related with the curricular units
Products:	reports in a log-book, posters, models, videotapes.

Comunication oriented classes

The teaching practice in these classes was very similar to the above-described one, but in addition to class and group discussions children had been engaged in the production of a newsletter that circulated within a small network of classes to keep it informed about the science activities.

The thought experiment was presented as part of a written questionnaire.

> Imagine to be in a foreign country and to meet there an animal that you have never seen before.
>
> - What can you understand of this animal by observing it for a while?

- What might you learn about that animal by observing it longer, even taking it to your home or to the lab in your school?

- Which kind of information would you search for on books or would you ask experts?

- What would you ask to local people ?

The questionnaires were presented during regular school hours by the experimenter who was willing to answer children's questions in order to make sure that they had understood the task. No time limit was set.

The dimensions that have been taken into account in the analyses are the following ones:

- *comprehension* of and *engagement* in the thought experiment

- *fluency* in predicting a range of informative elements and in identifying biological features that may possibly characterize the unknown animal (*categories of information*)

- *adaptive use* of learning strategies which is documented by: a) an incremental mentioning of categories in parallel with the change of the strategy proposed by each question; b) a pertinent matching between the inferred information and the kind of queried source.

Due to the limited number of children included in the sample (109), the results of the qualitative analysis can only reveal tendencies that is interesting to highlight but that only further assessements might confirm through a broader investigation.

FINDINGS

The task of "learning about an animal never met before" demands knowledge about the specific topic and meta-knowledge on strategies of search.

We have chosen a content rather familiar to children (knowledge about animals) for possibly enhancing the differences in meta-learning abilities among the students of the three sub-samples.

Before reporting about the differences among the school classes, we wish to display a repertoire of children's answers to the first question to give the flavour of the possible range of cognitive approaches to our request.

1 - "I touch it, I play, I stroke it"

2 - "I immagine to see a dragon and I can understand that he is good deep in its heart and that it behaves like that only because it is scared of man"

3 - "I would be sorry to see that it is lonely and i would realize how a mistreated animal can feel"

4 - "I can understand that this small animal can be sweet and loving"

5 - "I would understand that it is a very rare animal unfortunately, and I would try to remember all the peculiarities of it"

6 - "I immagine to be in New York and to explore a place where there is a Koala, Which I have never seen in my life. Things that I can understand are: that it lives on trees and also that it feeds on grass and leaves"

7 - "By observing the animal for a short while I would try to understand if it is afraid of me"

8 - "The animal is black, it is 2cm long and 7.5 cm large, it seems to belong to the animals having a carapace, it has a horn on its head, it has four thinn legs with two fingers"

9 - "I might understand which is its kind"

10 - ".....what it feeds on, if it is herbivore or carnivore"

11 - "Its general physical features: if it is four-legged or not, if it is a mammal or not, if it lives in a herd, and if it is a male or a female"

12 - "I might understand many things by observing the animal for a while: what it eats, how it reproduces, how it sleeps, if it is aggressive or calm, if it is scared or if it feels at ease even while I am there"

13 - "I might know its shape, how big it is, if it is friendly or fierce, what it feeds on, in which environment it lives"

14 - "Very little of its behaviour and its name"

15 - "I might understand that it lives well underground and that it is unable to walk on the ground"

16 - "By observing an animal which is new to me for a short time I might learn something about its behaviour"

17 - "By looking at an animal which is unknown to me I can understand that it is similar to some animal that I know and I can find the similarities"

18 - " I would look at the legs to check if they might belong to a "walker" or a"swimmer", and at the mouth if it is the mouth of a rodent or of a carnivore"

19 - "...its noszzle is similar to a branch of a tree, it sniffs and it looks like it is a searcher"

20- "I might tell its temper, if it is aggressive or tame and also its age from its fur and from the way it walks or runs"

Statements such as nos. 17,18 and 19 reveal the use of expert thinking strategies in the biological domain; their frequency was low.

We have included in five main categories the elements of information mentioned by children in all their replies to the the four questions in order to have an approximate description of the kind of biological knowledge that children have accessed when replying to the questionnaire. Anatomical and physiological features are the prevailing aspects which have been taken into account by all classes. In the DISC and COM classes these are followed by ethological aspects whilst in T classes are followed by Man/Animal relationship Ecological factors are relevant mainly for the pupils of DISC classes. Animal breeding is the less mentioned aspect in all the sample.

Comprehension

The task was perceived as a difficult one in almost all the school classes where it was presented. Children asked for many clarifications after reading the questionnaires and during the performance. They were troubled by the request of reasoning on an abstract "unknown" animal, without any concrete reference to a real one; also they had difficulties in recognizing

the cognitive goal of the task, which was to know more about an animal and not to establish a personal contact with it.

Statements such as n. 2, 3, 6 or like this one " It is a reptile, rather long, about three metres, with a triangular face and it makes people afraid" can illustrate these cognitive obstacles.

The degree of task's comprehension and acceptance by the pupils was measured by the number of missing answers, tautologies, mis-interpretations and un-informative answers. We have calculated their percentage on the total number of potential lack of answers to all the four questions.
Children of T classes evidently appear to be more disoriented by the task than the children of the other two sub-samples: lacking answers were 17.10% in IVth grade and 10.53% in Vth grade T classes versus respectively 0% and 2.5% in DISC classes and 1.47% and 0% in COM classes.

Fluency

The children of T classes were less fluent in guessing elements of information retrievable from each source. The average number of mentioned elements per child is: 1.10 in the T classes, 1.88 in DISC classes and 1.87 in COM classes. Differences are more marked among fifth grade classes.

Not only each child in T classes predicted a more limited number of informative elements, but the classes as a whole were able to identify a smaller range of categories of biological features. In fact 0.51 and 0.43 were the average numbers of categories identified by fourth and fifth grade pupils of T classes, in comparison with 2.41 and 2.85 of DISC classes and 2.52 and 2.94 of COM classes.

It has to be underlined that differences among these two last samples are not noticeable.

Adaptive use of strategies

The ability to regulate predictions or to adjust them when switching to another procedure or source of inquiry differed among the pupils of the three sub-samples but not outstandingly.

We have assessed this ability by two types of measures. One is an index expressed by the ratio between number of additional informative elements not previously mentioned (related with new categories of information) and the total number of mentioned elements. The other one corresponds to the percentage of children of the sub-sample who introduced new categories when they answered the question that followed the previous one.

The indexes of T classes resulted to be higher (i.e.closer to 1) than those of the other two sub-samples. The percentages in T classes appeared a little lower, particularly at the second question. It should be also taken into account that children of DISC and COM classes were more productive in mentioning informative elements and therefore they often re-introduced items besides producing new ones when answering each questions. Notwithstanding this fact, more children in these classes (respectively, 57,89% in DISC classes and 55,88% in COM classes compared with 46,49% of T classes) seemed to be aware that new biological features can be discovered when changing the source for getting information (long-term observation, books, people).

We finally comment on children's ability to correctly adjust categories to the information sources and therefore to make realistic inferences. This behaviour is certainly the most dependent on content knowledge.

We must point out that there are no clear cut criteria that can be applied for evaluating the correctness of replies, since the validity of inferred biological features depends to a great extent on the kind of animal that the child has evoked in his/her mind when producing an answer. Namely, features that can be acceptable in the case of a tiny animal are un-realistic if applied to a big specimen, or to a flying animal versus a terrestrial animal, etc. The great majority of children's replies appeared to be more or less appropriate from the point of view of a biologist. Only a small percentage of the mentioned items was clearly unrealistic and we exemplify them here:

Information source	predicted information
short-term observation	what it feeds on
	how it reproduces
	if it is rare
long-term observation	if it is an hunters' prey
	if it is going to be extinct
	its name
	how many species exist of it
	where does it come from
	where it is born
Information from books	if it is afraid
	what odours it has
	how it got lost

We have tried to adopt more exclusive criteria and we have selected two biological features as the most appropriate ones for each of the information sources. These are the features that more likely are made outstanding by the specific inquiry situation that was presented in the questionnaire; they were also present in the repertoire of categories that pupils had mentioned.

Animal's external features and aggressiveness have been chosen as targets for the first question. They are in the first two ranks in a scale of frequency of categories mentioned by children of all the three samples (about 40% of the mentioned items belongs to these categories) .Feeding habits and specific behaviours have been chosen for the second question. The first category is the most frequent in the answers of the DISC and COM classes, whilst the category "whether the animal can be tamed" is the most frequently mentioned by T classes. This category has the second rank in DISC classes together with that about specific behaviours.

Zoological classification and reproduction have been taken as the most appropriate categories for the third question. The first one has the highest frequency in all three samples followed by Feeding habits; the category Habitat is as frequent as Feeding habits in the DISC and COM classes, whilst it is almost absent in the T classes.

Reproduction is barely taken into account by all the classes (it is absent in T classes).
Chances to find the animal and man-animal relationship have been considered as the most appropriate categories for the last question. They are the most frequent in the DISC and COM classes, whilst in the T classes only the second one is as frequent as another category dealing with "to whom the animal belongs".

CONCLUSIONS

Not outstanding differences in disciplinary notions among the classes of the three sub-samples have been revealed by the questionnaire, although even under this respect the performance of the pupils of non-traditional classes appear to be better.

This result, though, enhances the value of the differences in meta-knowledge that the above-reported data suggest. The quality of the process of knowledge construction plays a very important role in how notions are used and become mental tools, a role that can be more crucial than in the acquisition of notions themselves. On the other hand, children of the classes in which apparently more elaboration had accompanied the inquiry approach did not outperform. in this questionnaire that certainly had limitations that need to be re-considered with further investigations.

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