PROMOTING STUDENT QUESTIONING IN THE LEARNING OF NATURAL SCIENCES

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ABSTRACT: This work aims to analyze the written questions asked by 9th grade students in three different question-promoting strategies in the subject of Natural Sciences, in order to assess the cognitive level and the functions of these questions. For this purpose, a qualitative research was implemented. Students' written questions posed in the three strategies were collected. A close relationship was not found between the type of strategy and the cognitive level of the students' questions. Nevertheless, the percentage of closed questions decreased throughout the three strategies while the percentage of open questions increased.

KEY WORDS: Questioning, natural science, biology, teaching strategies, learning

AIMS

Nowadays, one of the main aims of elementary and secondary education is the development of critical, reflexive and creative thinking, in order to provide students with the necessary tools to become active and autonomous citizens, as well as lifelong learners. These competencies can be achieved through the stimulation of students' active learning, namely through questioning. With this in mind, in this study we are concerned with the number and kind of questions asked by students in three different question-promoting contexts in the subject of Natural Sciences.

Thus, the main research aims of this study are as follows:

a) To analyze the written questions asked by 9th grade students in three different question-promoting contexts in the subject of Natural Sciences
b) To identify the question-promoting context that encourages more higher level questions;
c) To analyze how the characteristics of the question-promoting contexts influence the kind of questions students ask.

THEORETICAL BACKGROUND: STUDENT QUESTIONING

In recent years there has been an increasing emphasis on the important role that students' questions play in learning, as questions are an essential component of discursive activity, dialectical thinking (Chin & Osborne, 2008), and dialogic teaching (Wolfe & Alexander, 2008). Student-generated questions are an important element in the teaching and learning process (Albergaria Almeida, 2010, 2012;

Martinho, Albergaria Almeida & Teixeira-Dias, 2012), and play a significant role in motivating meaningful learning. In fact, some studies show that the promotion of a true spirit of inquiry can improve the quality of teaching and, consequently, the quality of learning (Teixeira-Dias, Pedrosa de Jesus, Neri de Souza & Watts, 2005).

The act of questioning encourages learners to engage in deep, scientific and creative reasoning. Given that asking questions is fundamental to science and scientific inquiry, Zoller, Tsaparlis, Fatsow, & Lubezky (1997) argue that the development of students' abilities to ask questions, reason, problem solve, and think critically and creatively should become a central focus of science education reform.

Students' questions result from a gap or discrepancy in their understanding or a desire to extend their knowledge in some direction. Students' questions may be triggered by unknown words or inconsistencies between the students' knowledge and the new information, which then engender «*cognitive disequilibrium*» (Graesser & Olde, 2003, p. 525). According to Graesser and Olde (2003, p. 525):

> Questions are asked when individuals are confronted with obstacles to goals, anomalous events, contradictions, discrepancies, salient contrasts, obvious gaps in knowledge, expectation violations, and decisions that require discrimination among equally attractive alternatives.

In spite of the educational significance of learners' questions, it is known that students generally are seen to ask few questions, and even fewer in the search of real knowledge. Pizzini and Shepardson (1991) argue that student questioning is influenced by instructional models and lesson structures and by the social structure of the classroom. Dillon (1988) also refers to the influence of the students' role as participants, and to the controlling function of the teacher's own questions. Pedrosa de Jesus, Teixeira-Dias & Watts (2003) consider that students will only engage in questioning if they are interested in the science topics studied. Clearly, if the classroom environment inhibits questioning, few questions will be asked.

METHODOLOGY

A qualitative research methodology of the naturalistic-ethnographic type was used (Denzin & Lincoln, 2000). This study was conducted with a Natural Sciences 9th grade class with 18 students (12 girls and 6 boys; mean age 14 years old). Once the researcher was also the teacher of the class, participant observation was the main source of the data. Three question-promoting strategies were designed and implemented, throughout the subject unit about the morphophysiology of the circulatory system:

- Strategy 1: watching a movie - the researcher showed a short movie about the heart to the class. Students were invited to write their doubts and questions abut the movie.
- Strategy 2: laboratory work - students performed a laboratory work that consisted of the dissection of a cow's heart. In order to carry out the collection of written questions, the researcher has developed a data collection instrument, which consisted of a report in the form of Gowin's V.
- Strategy 3: reading a text - students were encouraged to formulate questions after reading a science text about the cardiac cycle. This text was provided by the researcher.

> At rest, the average heart beats 70 times a minute and pumps approximately 7200 liters of blood per day, or 5 liters per minute. When the heart beats, you will hear the sound lâb-dâp caused by the closing of the valves. The lâb is the atrioventricular valve closure sound. The dâp is the sound of the closing of the aortic valve, after the blood have left the ventricles. Thus, the cardiac cycle is heard as lâb-dâp, lâb-dâp, pause, pause, pause, dâp-lâb ...

Fig.1. Small text about the cardiac cycle provided to the students (strategy 3).

After reading this small text the students were asked to raise questions that should start with the following words: *What if?, Why?, How?,* or *Write another kind of question.* Giving the students the previous words, we aimed to avoid that they would pose basic or closed questions, usually started by *What, Where* and *Which*.

All students' written questions were collected and content analysis was carried out. The main findings are presented in the following section.

RESULTS AND DISCUSSION

All students' questions were categorized according to their cognitive level (closed or open) and their function (knowledge, understanding, relationship, evaluation and finding a solution). Table 1 shows the main characteristics of each category. We must emphasize that to be included in a specific category, the question does not need to begin with one of the typical expressions. These expressions or words are usually associated to a specific kind of question, but there is not a direct link between these typical expressions and the cognitive level or function of the question. For instance the question «*Are there diseases directly related to the change of the cardiac cycle?*» was classified as an information question, even if it does not start with *What*, *Where* or *Which*.

Table 1.
Categories of questions and their main characteristics

Cognitive level	Function	Characteristics	Typical expressions
Closed questions (Low level)	Information	Questions that ask for specific information and/or facts Direct and non complex answers; sometimes the answer is just «yes» or «no»	What…? Where…? Which…?
	Understanding	Questions that require explanations that can help the students to understand a concept, a fact, a phenomenon, a task or a procedure. Do not have a simple or direct answer	Why…? How…?
Open questions (High level)	Relationship	The student aims to understand causes and/or consequences These questions relate two or more concepts	Which is the consequence? Which is the difference…? What happens…?
	Evaluation	The student tries to find guidance to make decisions or to express his/her own opinions These questions show the students' points of view, their choices and their judgments	Which is the best…? What's the opinion…? What do we think about…?
	Finding a solution	These questions aim the understanding of parts of a complex problem The answer implies the identification or resolution of a problem	What if? If… then…?

In Table 2 examples of the questions asked by the students in each one of the question-promoting strategies are presented, as well as their classification.

Table 2.
Examples of questions

Cognitive level	Function	Examples of questions	Strategy
Closed	Information	Which ventricle is more muscular? Which is the path of blood? Are there diseases directly related to the change of the cardiac cycle?»	Video Laboratory work Text
	Understanding	How does the heart pumps blood to the whole body? How does the myocardium pumps blood to itself? How does the valves always regulate the same amount of blood?	Video Laboratory work Text
Open	Relationship	What happens if the blood from the right ventricle mixes with the blood from the left ventricle? Which are the consequences of the accumulation of fat in the heart? Why? What happens when a person has heart failure?	Video Laboratory work Text
	Evaluation	-- (students did not formulate questions of this type) Having high blood pressure depends on the beating rate of the heart? -- (students did not formulate questions of this type)	Video Laboratory work Text
	Finding a solution	How is it possible for the blood to go from our feet to our head if there is gravity that pulls everything down? -- (students did not formulate questions of this type) What if after the passage of the blood the valves do not close?	Video Laboratory work Text

Throughout the three strategies, the students asked 194 questions. The distribution of these questions according to their cognitive level and their function is shown in Figure 2.

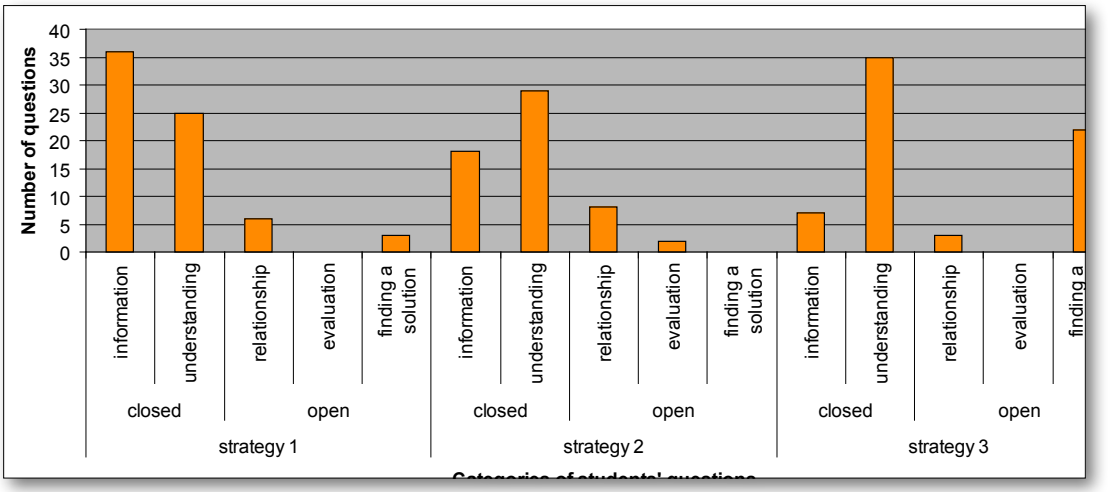

Fig. 2. Number, cognitive level and function of students questions.

The number of closed questions (n=150) was much higher than the number of open questions (n=44). However, there was a progressive decrease in the number of information questions over the three strategies (Figure 2). In the first strategy, 36 information questions were asked, decreasing to 18 at the laboratory work strategy, and to 7 at the third strategy. In the understanding category, the number of students' questions has evolved over the three strategies. In the first strategy, students formulated 25 understanding questions, 29 in the context of laboratory work, and having reached its maximum in the third strategy, with 35 understanding questions. Thus, we can conclude that regarding closed questions, the students were gradually improving their quality over the three strategies.

It should be noted that in the second and the third strategies (laboratory work and reading a science text), the number of understanding questions was higher than the number of information questions. This could be related to the type of strategy. In the laboratory work students showed curiosity to understand the internal structure of the heart as well as its physiology. Consequently, they have formulated a larger percentage of understanding questions, which require explanations that can help students to understand a concept, an idea, a fact, or a phenomenon. Similarly, in the third strategy (reading a scientific text), students have formulated questions whose answers allowed them to understand the cardiac cycle, an issue addressed in the text, and which had not yet been approached in science classes.

All strategies produced open questions. Regarding this category of questions, the students asked two evaluation questions, 17 relationship questions and 25 finding a solution questions. The 2 evaluation questions were formulated in the context of laboratory work. This result leads us to the conclusion that this context provided a suitable stimulus for students looking for guidance, so that they could make decisions and formulate their opinions about the subject, in this case the morphophysiology of the heart. However, this small number of evaluation questions can be related to the fact that this kind of questions demands a high reasoning ability, that students of this age haven't reached yet. It is important to emphasize that 22 of the finding a solution questions were posed during the third strategy. The cardiac cycle was approached for the first time throughout this strategy, and maybe this is the reason for such a large number of finding a solution questions. The students were facing a new topic, and they were trying to find answers to their doubts.

Finally, it is important to underline that the strategy 1 was the one that produced a larger number of questions, but it was also the strategy that originated the larger number of closed questions. The last strategy was the one producing a larger number of open questions. It seems that students need to practice their questioning ability in order to enhance it and to make use of it in a full mode.

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