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Knowledge gaps on objects about which little is known: Lack of knowledge leads to questioning on basic levels of an ontological branch

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ABSTRACT

This study examined the role of knowledge in asking questions on objects about which little is known, a situation hitherto explained in terms of a passive knowledge deficit hypothesis. Seventh grade students were tested for knowledge about a sample of familiar and unfamiliar objects typically studied in science classes. Then they were asked to make explicit what they did not know about the objects by asking questions about them. The results showed that the participants asked general questions, i.e., questions that were applicable to superordinate categories more frequently on the unfamiliar objects than on the familiar objects. This substantiates a relation already described in the literature: more global questions are associated with less knowledge of a questioner. More importantly, the findings are consistent with an active role of knowledge, namely knowledge about superordinate categories, in generating questions about a little known object.

1. Introduction

Being aware of what is unknown or not understood or, more generally, knowing when one has not achieved a certain learning state is regarded as fundamental in self-regulated learning (Hacker, Dunlosky, & Graesser, 1998; Schunk & Zimmerman, 2003) or in problem-based learning approaches where students are encouraged to set their own problems (Chin & Kayalvizhi, 2002; Gallas, 1995). It is also critical to such an educationally relevant activity as question asking. Asking information seeking questions is a process involving stages of anomaly detection, question articulation, and social editing (Graesser & McMahen, 1993). The awareness of what is unknown or not understood or the recognition of "anomalies, obstacles, gaps or inconsistencies" (Graesser & McMahen, 1993) leads to questioning, although the particular processes involved in noticing each of these difficulties may be different and not always simple (Otero, 2009).

This study focuses on the awareness of knowledge gaps that lead to questioning and on one variable that may influence this awareness: domain knowledge. We analyze the role of domain knowledge in questioning about an object when this knowledge is scarce. In particular we examined the detection of knowledge gaps about a sample of objects normally included in the school science curriculum, and the consequent quality and quantity of questions asked by 7th grade students who knew little about some of these objects.

1.1. Hypotheses on knowledge and questioning

The role of knowledge in question asking has been analyzed in terms of a *knowledge clash* hypothesis and a *knowledge deficit* hypothesis (Otero & Graesser, 2001). The first would apply in situations where there is an inconsistency between information and the questioner's knowledge or an inconsistency between pieces of information. This results in "conflicts", already analyzed by Berlyne (1954) and Berlyne & Frommer (1966) as one cause leading to questioning. For instance, a student who read a text that explained the white color of clouds in terms of light scattered by water droplets asked the following question: "When it rains, light impinges on water drops and a rainbow is formed. Why is it that clouds are white and a rainbow is colored?" (Otero & Graesser, 2001). The question exemplifies the result of a clash between the knowledge of the student regarding rainbows and the information in the text about the effect of incident light on the water droplets that make up clouds.

According to the knowledge clash hypothesis, more knowledge would provide more opportunities to detect information inconsistent with the questioner's knowledge. This would lead to questions that a less knowledgeable questioner would not ask. Indeed, several studies have found such a positive effect of knowledge on questioning. Scardamalia and Bereiter (1992) found that children asked more questions of a challenging nature reflecting knowledge based speculation on the topic of endangered species, a topic that was familiar to them, than on fossil fuels, a topic that was less familiar. The participants in the studies of Grasser and Olde (2003), and Graesser, Lu, Olde, Cooper-Pye, and Whitten (2005) were instructed to ask questions in order to identify the components responsible for malfunctions in devices such as cylinder locks. The results showed that technical knowledge enabled students

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to ask fine-grained, elaborated questions, focusing on likely malfunctioning parts, in contrast to low knowledge students who asked unfocused and misdirected questions. Vaz, Fernandes, Morgado, Monteiro and Otero (2014) analyzed the relation between knowledge and the questions that 7th and 12th grade students asked on a sample of objects about which they had significant differences in knowledge. Among other findings, the study showed that the more knowledgeable, older students, asked significantly more elaborated questions than the younger students, with less knowledge.

However questions may be asked without the questioner having knowledge that is inconsistent with the information provided. For example, when requested to state what she would like to know about the cornea, a student participating in our study asked "What problems may occur in the cornea?" No apparent knowledge clash exists here, and questioning would be rather explained by an alternative hypothesis: the knowledge deficit hypothesis (Otero & Graesser, 2001). Knowledge gaps, such as not knowing what kinds of diseases are associated with the cornea would activate questioning. Therefore, according to this hypothesis the less one knows, the higher the probability of asking a question because knowledge gaps would be more frequent.

A puzzling situation results from the acceptance of the two hypotheses: extant knowledge plays a positive, active role in question asking according to the knowledge clash hypothesis, but its *absence* also plays a positive role according to the knowledge deficit hypothesis. This study looks at a situation of the latter type, claiming an active role for knowledge also when it is scarce.

1.2. Questioning about an object when little is known about it

Studies such as those mentioned above about the effect of knowledge on questioning also offer a glimpse about the effect of lack of knowledge on the type of questions asked. Several of them share the finding that less knowledge is associated with more general, unspecific or imprecise questions. These are questions that may be asked about a wide range of entities and not only on the object or process under consideration. In Scardamalia and Bereiter's (1992) study, for instance, more than half of the questions asked by the students on the less well known topic of fossil fuels were "basic information" questions, such as "What are fossil fuels?" or "What are fossil fuels made of?". Also, in the study describe above, Grasser and Olde (2003) found that the low technical knowledge participants, in contrast to high knowledge students, asked diffuse and shallow questions, as well as questions on components that would not explain the breakdown. Vaz et al. (2014) also found differences in the proportion of general "What is X?" questions asked depending on the knowledge of the questioners. They were more frequently asked by the younger, less knowledgeable students than by the older students. And within any of the grade levels, they were asked more frequently on the less well known objects of the sample than on the better known objects.

There are other studies on questioning that converge on these findings. Roth and Roychoudhury (1993) studied 8th grade and 11th grade science students in the context of an open-inquiry laboratory. They found that the students doing experiments in an unfamiliar domain started asking unfocused questions on vague, general variables such as "type of plants" and "amount of light", that were measured qualitatively only. Over the course of the project the questions became more focused involving more specific variables. Van der Meij (1990) compared the production of questions on unknown words, such as "tardy", by low knowledge and high knowledge 5th grade students. He found that more global questions, i.e., those reflecting "a somewhat unspecified search for information about a target word (p. 506)" were produced by the low knowledge students than the high knowledge students.

In sum, all the previous results suggest an inverse relation between the knowledge associated to an object and the generality of the knowledge gaps that activate questions about this object: the lesser the knowledge, the more frequent general knowledge gaps expressed by global, diffuse, or unfocused questions would be. An example could illustrate this relation. A student who is asked to make explicit her knowledge gaps about a refrigerator may ask a question such as, "What is its electrical consumption?" This involves knowing that a refrigerator is a device that uses electrical energy. However, such a question would not be expected if the student were requested to ask about an unfamiliar device, X. More general questions such as "What is X for?", may be possible in this situation, based on the knowledge that devices are artifacts and therefore they are built to fulfill a specific role. In fact, such questions could be asked on any device, whether it is a LED, an umbrella or an unknown device X. If a student lacks knowledge about the energy requirements of X, a more precise question such as "What is X's electrical consumption?" would not be a sensible question to ask because there is no knowledge supporting the assumption that X works using electricity.

Therefore less knowledge appears to be associated to questions that may be sensibly asked about more general categories. This hypothesized relation can be made more precise borrowing the notions of "predicability" and "spanning" that were analyzed by Keil (1979, pp. 10–18) in relation to the organization of ontological knowledge. Predicability is based on the notion that predicates cannot be sensibly associated to any term: "[A] predicate spans a term if and only if that predicate-term combination makes sense and can be assigned a truth value, which can be either true or false (p. 11)". For instance, "blue" can be predicated of "banana" although it may be false. However it cannot be sensibly predicated of "intuition" because it is impossible to assign a truth value to the proposition "The intuition is blue". Therefore "blue" spans the term "banana" but does not span "intuition".

More importantly for our purposes, spanning is associated to the hierarchical relations existing between categories (Keil, 1979; Sommers, 1965). If term *a* belongs to category *A* ("Device", for instance), and term b belongs to category B subordinate to A ("Battery", for instance), the predicates spanning A are a subset of the predicates spanning B. That is, there are predicates such as "rechargeable" that span "battery" but that do not span other terms belonging to the category "device" such as "pulley" (because a pulley does not perform functions involving electric charge).

The notion of spanning may be used to assess the generality of a question by considering the ontological level of the category to which the question may be sensibly addressed. Take a lexical database such as Wordnet (Fellbaum, 1998) that provides an ontological hierarchy of lexicalized entities. "Battery", for instance, has as hypernims of increasing generality, "electrical device", "device", "instrumentation", "artifact", "whole", "object", "physical entity", and "entity". A question that may be addressed to the category "battery" is "How does it transform chemical energy into electrical energy?". However it cannot be sensibly addressed to more general categories. In particular it cannot be sensibly asked on all kinds of electrical devices. For instance, an antenna is an electrical device, and asking how it transforms chemical energy into electrical energy would not make sense because this device does not perform such a transformation. Therefore this question, when asked on a battery, would correspond to the lowest level of generality because it would span the category battery, but not the category device nor any other above. However, consider the question "What is the biggest battery?" It may be sensibly asked not only on batteries but on any electrical device or, in fact, on any object—a category located at the 6th level in Wordnet's taxonomical branch of battery. Therefore it is considered to be a more general question.

According to the previous rationale we tested the hypothesis that the knowledge that a questioner has about an object should correlate negatively with the generality of the questions asked on this object. Such correlation would be consistent with the use of knowledge about superordinate categories when questioning about a little known target object.

In order to examine the previous hypothesis, we tested 7th grade students for knowledge about a sample of objects typically studied in