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Using online measures to determine how learners process instructional explanations

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ABSTRACT

The goal of the present study was to examine the mechanisms underlying a strategy that we developed to make instructional explanations effective. In two experiments participants learned about plate tectonics from a multimedia material, including adjunct explanations that revised common misunderstandings. These explanations were either marked (including a device that pointed out the misunderstanding that the explanation was intended to revise) or unmarked. In both experiments participants receiving marked revising explanations outperformed those receiving unmarked ones in retention and transfer. In Experiment 1, think-aloud protocols revealed that marked revising explanations enabled learners to detect and repair flaws in their understanding more frequently than unmarked explanations. In Experiment 2, time recordings revealed that participants in the marked condition spent more time processing the revising explanations. Overall, the results mean that the revising instructional explanations that point out learners' misunderstandings promote a revision-oriented processing, in which learners monitor and revise their own understanding.

1. Introduction

Imagine some learners studying about plate tectonics. Imagine they have mixed up the features of two kinds of plate collision, which results in the wrong assumption that there can be volcanoes in the Himalayas, such as happens in the Andes. As a teacher, you might provide these learners with an instructional explanation with the goal of revising their understanding: "In the Andes, cracks are formed through which magma surfaces, forming volcanoes, whereas in the Himalayas two continental plates crash so that the collision is head on, forming mountains." As can be seen, this comment addresses the learners' misunderstanding and is intended to aid in the revision and repair of this misunderstanding. Accordingly, this kind of comment can be called *revising instructional explanation* to distinguish it from standard instructional explanations, which are devoted to conveying contents to learners who still know very little about a topic.

There is evidence indicating that revising instructional explanations are not beneficial to learning (Chi, Siler, Jeong, Yamauchi, & Hausmann, 2001; Schworm & Renkl, 2006; Webb, 1989). Our interpretation of this evidence is that revising instructional explanations are not clearly presented to learners as a response to their misunderstandings, which can make learners perceive the explanations as redundant, secondary information. In order to make revising instructional explanations appear responsive, one strategy is to point out the specific gaps and flaws in learners' understanding that the explanation is about to revise before providing it. We have called this strategy the *marking technique*. In the example we are considering, marking would consist of something like this: "You see that there are common features in the plate collisions of both the Himalayas and the Andes, such as two plates colliding and the corresponding ground elevation, and this is true; however, what you do not see is the fundamental differences between the two collisions: Volcanoes exist in the Andes but not in the Himalayas!"

The marking technique has proved to be effective (Acuña, García Rodicio, & Sánchez, 2011; Sánchez, García Rodicio, & Acuña, 2009). The goal of the research presented here was to understand how the marking technique works. To do so we used two online measures, think-aloud protocols and reading times. The results have theoretical implications, as they clarify the conditions under which

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learners learn from instructional explanations, and practical implications, as they provide guidelines about how to present instructional explanations effectively.

2. Revising instructional explanations: why are they often ineffective?

Two kinds of instructional explanations can be distinguished depending on their goal (Wittwer & Renkl, 2008). One kind is given when learners have little knowledge of a given topic and aims to provide a basic understanding of the topic: *Standard instructional explanations*. Another kind is provided when learners have already gained some knowledge and aims to revise eventual gaps and flaws in their understanding: *Revising instructional explanations* (*RIEs* henceforth). We are interested in this latter kind.

RIEs, as shown in the previous example, address gaps and flaws in learners' understanding and can help in their revision. However, RIEs do not seem to be so effective, as suggested by several studies. Chi et al. (2001) asked participants to learn biology from a textbook and maintain a dialog with a tutor. Tutors provided participants with multiple aids, including corrective explanations following an error. These explanations were not associated with learning. Webb (1989) reviewed a set of studies of peer-tutoring in mathematics and computer science. In peer-tutoring sessions, students received an introductory lesson and worked collaboratively to solve a task. Receiving explanations from a peer after having made an error or having requested for help was rarely associated with learning. Schworm and Renkl (2006) asked participants to learn about instructional design from a set of solved examples, preceded by an introduction. Half of the participants were required to explain the rationale underlying the examples. In one condition, participants received instructional explanations on demand, which should contribute to optimizing their self-explanations. In another condition, participants were not provided with instructional explanations. Participants in the former condition performed worse in a posttest. The instructional explanations in these studies can be considered RIEs, as they attempted to revise learners' already gained understanding in some way. Overall, RIEs were not effective.

One possible interpretation for this ineffectiveness is that although RIEs address learners' gaps and flaws in understanding, they do not point out that fact. That is, RIEs do not tell learners that they are intended to solve a specific problem in learners' understanding. This form of presentation may make learners perceive RIEs as redundant, secondary information instead of as revising, useful information. This perception, in turn, may make learners underuse the RIE, instead of exploiting it as a basis for revising understanding. Based on this rationale we developed a strategy to make RIEs effective.

3. The marking technique

The marking technique consists of pointing out the gaps and flaws in learners' ongoing understanding that the RIE is designed to revise before providing the RIE. Implementing the technique takes several steps.

First, it requires pilot studies to identify common misunderstandings that learners develop when studying a given topic. In our studies (García Rodicio & Sánchez, 2012), participants solved retention and transfer tests, thought aloud, or answered critical questions while learning about plate tectonics from different materials. We identified four kinds of misunderstandings in participants' protocols/answers. In *causal confusions* (30%) participants inverted the elements of a causal relationship (e.g., "plate crashes create ridges"; actually, ridges create plates by dividing the earth surface into pieces). In *causal simplifications* (30%) participants attributed certain effects to far causes, instead of to near ones (e.g., "magma creates mountains"; actually, magma pushes plates, which crash with each other, forming mountains). *Spatial confusions* (13%) consisted of locating incorrectly a critical element (e.g., "plates are within the mantle"; actually, they are on the mantle). Finally, *label confusions* (27%) were wrong label-entity associations (e.g., "the area where crust is destroyed is referred to as a ridge"; actually, it is a trench). Overall, most of the misunderstandings (60%) were directly related to the causal chains of the conceptual system (causal confusions and simplifications) whereas the remaining errors (40%) were related to aspects subordinate to these chains (spatial and label confusions).

Once these misunderstandings are identified, one has to construct the corresponding RIEs. Since in our studies all misunderstandings were (directly or indirectly) related to the causal chains of the conceptual system, we constructed RIEs that emphasized the relationships between the elements in these causal chains (see Fig. 1, lower part). Accordingly, these RIEs were causal-based explanations.

The final step is combining RIEs with *warning messages*. These are devices that point out the specific misunderstanding that the RIE is expected to revise. They capture learners' current understanding, point out it is wrong, and explain why it is so (see Fig. 1, upper part).

In order to test the effectiveness of the technique, one has to compare the effects of a RIE including a warning message, a *marked RIE*, with those of an *unmarked RIE*, which is a RIE without warning message. Four comparisons showed that participants receiving marked RIEs performed better in retention and transfer, relative to those in the unmarked condition (Acuña et al., 2011; García Rodicio & Sánchez, 2012; Sánchez et al., 2009). An interesting question is

After attending these modules, what you probably see is that in both the Andes and the Himalayas two plates collide, forming mountains.
Although correct, this idea is not enough to completely understand how plate collisions work.
What you probably did not realize is that collisions in the Andes and the Himalayas have big differences, critical to understand the modules.
Here you have an explanation going into these differences in depth.

In the Himalayas two continental plates are crashing, that is, plates with identical weight and size. Therefore, the collision is head on.
Conversely, when one of the plates is oceanic, as in the Andes, plates have different weight and size. Because of that, the oceanic plate, which is heavier, sinks under the continental plate and melts in the mantle.
Moreover, continental plates in the Himalayas push each other, thus folding up and forming mountains without volcanoes.
What happens in the Andes is that the sinking plate puts a lot of pressure on the continental plate, which lifts the continental plate and forms cracks in it through which magma from the mantle surfaces, forming mountains with volcanoes.

Fig. 1. An adjunct instructional explanation (RIE) addressing a common misunderstanding (below) preceded by a warning message pointing out the misunderstanding (above).