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ABSTRACT

This paper presents a study of 64 undergraduate students on the use and evaluation of scientific information. To assess scientific claims as they encounter them in everyday life, students need to gather information. Previous research suggests that a frequent first step is to generate an unsubstantiated casual explanation. This process could improve the search for new information or introduce strategies that lead to bias and distortion. The effect of explaining claims on the information-gathering process is examined in the context of investigating ecological problems. Explaining is manipulated as is the presence of alternative hypotheses, a common treatment for the undesirable effects of explanation. Results indicate that explaining a claim shifts the search away from covariational data that establishes the existence of a relationship and toward the gathering of noncovariational information about underlying mechanisms. This shift is partially prevented by the presence of alternatives. It is suggested that this shift is undesirable. Educational implications are discussed. (Contains 19 references.) (Author/YDS)

Helping students ask effective questions about scientific claims: Navigating the "sound bite" environment

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Abstract

To assess scientific claims as they encounter them in everyday life, students need to gather information. Previous research suggests that a frequent first step is generating an unsubstantiated causal explanation. This process could improve the search for new information, or introduce strategies that lead to bias and distortion. The effect of explaining claims on the information-gathering process is examined in the context of investigating ecological problems. Explaining is manipulated, as is the presence of alternative hypotheses, a common treatment for the undesirable effects of explanation. Results show that explaining a claim shifts the search away from covariational data that establishes the existence of a relationship, and toward the gathering of noncovariational information about underlying mechanisms. This shift is partially prevented by the presence of alternatives. It is argued that the shift is undesirable, and educational implications are discussed.

Recent assessments of science education emphasize the importance of science literacy, i.e., the ability of students to use and evaluate scientific information in their everyday lives with confidence (American Association for the Advancement of Science, 1993; National Research Council, 1995). This can be quite a challenge; popular sources of scientific information often fail to provide the details needed to conduct a critical analysis. Reporting may only include the scientists' conclusions, without explaining the data and processes that led them to make these claims (Brem, Weems & Russell, in preparation). Thus, if students are going to critically evaluate and use scientific information, they may have to fill the gaps for themselves.

Brem and Rips (1995; in press) demonstrated that participants introduce unsubstantiated narrative explanations into arguments when evidence is lacking. Put simply, people tell stories about what <u>might</u> happen when data concerning what <u>actually</u> happens are missing. Given the dearth of information that may be available to students as they encounter science in their everyday lives, it is likely that they will engage in these speculative stories.

And an explanation might not be a bad place to start. Ideally, we would like students to use the explaining process to figure out what they know and don't know, and then seek out whatever additional information they require to make a decision. Explanation has been shown to improve comprehension, transfer, and skill performance (e.g., Palincsar & Brown, 1984; Chi, deLeeuw, Chiu & LaVancher, 1994; Smith & Goodman, 1984), and increase sensitivity to patterns in data (e.g., Wright & Murphy, 1986; Jennings, Amabile, & Ross, 1982). However, the body of literature touting the advantages of explanation is matched by an equally large body warning of pitfalls. Explanation has been shown to lead to bias and distortion in the search for and interpretation of evidence (e.g., Chapman & Chapman, 1967, 1969), and overconfidence (e.g., Ross, Lepper & Hubbard, 1975; Koehler, 1991). Therefore, it is an open question as to whether explaining will have a desirable or undesirable effect in the popular media environment, motivating this study.

There are a number of ways explaining could help or impede the ability to seek information and critically evaluate scientific claims; I consider only two of those here.

Information Goals

First, explaining may affect our goals in seeking information. For example, suppose we hear a story on a headline news channel that the number of red-crested hawks (a fictional species) in California is plummeting, and scientists are blaming the drop on the timber industry. Thus, the scientists are making the claim:

> *Redwood harvesting is causing a decline in the population of red-crested hawks.*

As concerned citizens, we want to know whether this is claim is well-backed by evidence, but the broadcast doesn't deliver the goods. What can they do? We can identify two rough categories of goals: Establishing *existence* and establishing a *causal story.* If we wish to establish existence, we would attempt to confirm that redwood harvesting reliably causes a decrease in the number of hawks, and that harvesting is not confounded with other factors. If we wish to establish a causal story, we can attempt to determine why there is a link between harvesting and hawk decline. For example, harvesting may be robbing the hawks of nesting sites, or the equipment used in logging may be producing toxic levels of pollutants.

While establishing a mechanism is scientifically important, until we determine that there is a link between harvesting and the decline, such a search may be a waste of time and effort. Also, if we immediately jump to testing a particular mechanism—say, a lack of nesting sites—and there turns out to be no evidence for this particular causal path, we have to start again. We may have ruled out one way of linking harvesting to the decline, but we've not ruled out the possibility of a link. Worse yet, given the persuasive properties of explanations, it could result in an unwarranted attachment to a false assertion. Telling ourselves why harvesting *should* lead to a decline may convince use that it *does.* Of course, establishing existence without a mechanism—mere association—is also inadequate. But the most efficient course is to make sure there is something worth explaining before going further.

Because explanations focus on underlying mechanisms, I predict that explaining will increase the number of questions serving Story goals as students fail to attend to Existence goals.

Information Type

Second, explaining may affect the kind of information students seek. Both Story and Existence goals can be served by collecting the same sorts of information. In other research the focus has been on the distinction between covariational and noncovariational information (e.g., Ahn, Kalish, Medin & Gelman, 1995; White, 1995; Lalljee et al., 1984).

Covariational information refers to data concerning the presence or absence of an effect in the presence or absence of the proposed cause. For example, if the claim is that redwood harvesting is causing a decline in the hawk population, we could test this claim by asking the following questions:

1. *Is the population declining in places where harvesting is occurring? (cause present/effect present)*
2. *Is the population declining in places where no harvesting is occurring? (cause absent/effect present)*
3. *Is the population stable in places where harvesting is occurring? (cause present/effect absent)*
4. *Is the population stable in places where no harvesting is occurring? (cause absent/effect absent)*

These questions represent the four cells of the covariation matrix created by crossing the presence or absence of the proposed cause with the presence or absence of the target effect. The strongest evidence in favor of the claim would be "Yes" to questions 1 and 4, and "No" to questions 2 and 3. We could also test the pollution mechanism in the same way:

1. *Is the population declining in places where pollution (of the sort harvesting creates) is high? (cause present/effect present)*
2. *Is the population declining in places where pollution is low? (cause absent/effect present)*
3. *Is the population stable in places where pollution is high? (cause present/effect absent)*
4. *Is the population stable in places where pollutions is low? (cause absent/effect absent)*

Thus, both Existence and Story goals can served by collecting covariational data. Covariational data is often thought to be the strongest (Kuhn 1993); even when certain cells are missing, collecting covariational information can be informative (Klayman & Ha, 1987).

However, researchers have found that people often show a bias for noncovariational information when making and evaluating causal attributions (Ahn et al., 1995; Lalljee et al., 1984; White, 1995). For example, we might ask "Do the hawks nest in dwarf redwoods?" or "Does harvesting produce pollution?." These questions are noncovariational, in that they do not equate the process of making causal attributions with the process of matching cause and effect. Previous studies have equated noncovariational information with "mechanistic" information, or "hypothesis-testing," making it roughly equivalent to Story goals. I would argue, however, that either sort of goal may be served by collecting covariational information. Likewise, although perhaps it seems redundant, one could just as easily ask "Does harvesting hurt the hawks?" and thus ask a noncovariational question about an Existence goal. If students tend not to do this, that is an empirical finding rather than a theoretical necessity.

The distinction between covariational and noncovariational questions is important because it indicates the questioners' focus and their approach to the problem of gathering evidence. The difference between them points to the questioners' representation of the problem. When questioners phrase their requests as covariational questions, they are thinking not only in terms of what information they want, but explicitly considering relevant comparisons and dimensions. Noncovariational questions present a less well-defined request. While this does not rule out the possibility that the questioner is actually thinking in terms of the covariational data necessary to obtain this information, if there are systematic shifts from covariational to noncovariational questions, this may reflect a shift in problem representation.

From a pedagogical standpoint, we would like students to approach the information gathering process in a way that maximizes their opportunities for getting what they need, and a covariational approach is preferable to a noncovariational one in this respect. The less specific a question, the more ways it can be interpreted. "Does harvesting lead to pollution?" will no doubt get very different answers from conservationists and loggers; thus a more specific question that specifies what comparisons we would like to see is more desirable. Of course, the process of specifying a test is far more complicated than simply setting up appropriate dimensions of comparison—defining "pollution" and what constitutes high and low levels of pollution and harvesting is open to debate. But, generally speaking, the more specific students can be, the less vulnerable they are.

Although the issue of covariation can be theoretically separated from the issue of goals, previous studies have noted a strong relationship between noncovariational information and Story goals. When people pursue the mechanisms underlying a relationship, they often do so using noncovariational methods. If explaining could leads to a rise in Story goals, it may be paralleled by a decrease in requests for covariational information.

In summary, explaining may lead to a larger number of noncovariational questions, as well as a failure to attend to Existence goals in favor of Story goals. Therefore, I also considered the effects of a well-documented antidote to the problems induced by explanation—the presence of alternative hypotheses. Many studies show that considering alternatives reduces participant confidence (for a review, see Koehler, 1991). The more possibilities that exist, the less certain we are that any one possibility is the right one (Kuhn, Flaton & Weinstock, 1994; Anderson, Speer & New, 1984). However, previous work has not addressed precisely how this uncertainty affects a person's search for information. Do they simply lose confidence in their own judgment? If so, their presence should not counteract shifts induced by explaining. If alternative hypotheses encourage greater scrutiny and more rigorous testing, their presence should, relative to explaining in the absence of alternatives, increase the number of covariational questions.

Method

Students were presented with primary claims about ecological problems, couched in a short introductory paragraph designed to simulate the tone of a headline news report. Students' task was to formulate three questions that they would pose to an expert in order to assess the claim's validity. It was stressed that their job was to evaluate the claim, not any particular mechanism that might underlie the claim. We created four conditions by manipulating whether the primary claim was presented alone or with an alternative, and whether students did or did not generate an explanation for the claim.

Participants. Sixty-four undergraduate students participated.

Materials. Eight items were generated, each describing an ecological problem. The problems were fictional, to assure that students could not bring existing knowledge to bear. Each item consisted of a brief introductory passage, a primary claim asserting the cause of the problem, and an alternative claim asserting an alternative cause. (See Table 1 for an example.)

Design & Procedure. A 2X2 between-participants factorial design was used. The independent variables were Explanation, with two levels (Explanation vs. No Explanation), and Alternatives, with two levels (Alternative Present vs. Alternative Absent). Across participants, all items appeared in all conditions. The order of item presentation for each participant was randomized.

Table 1. An example of the items used.

Since the beginning of this decade, there has been a sharp decline in the population of red-crested hawks in California. The decline has been so pronounced that the red-crested hawk will soon qualify as an endangered animal unless the cause of its decline can be determined and removed.
The following claim regarding the decline of the red-crested hawk has been made:
Unchecked harvesting of dwarf redwoods is causing a decline in the number of red-crested hawks.
***(Alternatives Present* condition only):**
Others have criticized this claim, and argue that the harvesting of dwarf redwoods has nothing to do with the decline. Instead they claim that:
A decline in the field mouse population is causing a decline in the number of red-crested hawks.
***(Explanation* condition only):**
We would like you to now try to make up an explanation for the effect the first claim describes. What specific set of events might lead from the **unchecked harvesting of dwarf redwoods** to the decline in the number of red-crested hawks?

All participants read the introductory passage and primary claim. In the Alternative

Present condition, participants also read the alternative claim, and this claim was included in every activity they completed.

Participants in the Explanation condition were instructed to explain how the stated cause in the primary claim could lead to the problem described. Having explained each of the eight claims, they were told to imagine that they had access to an expert, of whom they could ask any question, and to generate three questions that would help them to determine whether the primary claim were true. It was stressed that they were assessing the claim, not any particular underlying explanation, and an example was provided.

Participants in the No Explanation condition read the initial passage and claim(s), then proceeded directly to the question generation task. This was designed to interfere with spontaneous explanations they might entertain. In all other respects, the instructions and tasks were identical to those used in the Explanation condition.

Results

A blind rater coded students' questions with respect to goal and type of request (Table 2):

- **(a)** Information Goal: Existence or Story. The coder also had the category "Neither" available for questions regarding general background information (e.g., which company was conducting the harvesting, what harvested trees are used for). These responses were omitted from the analysis.
- **(b)** Information Type: Covariational or Noncovariational.

The rater also categorized questions as to whether they addressed the primary claim, or an alternative (either a presented alternative or student-generated one). Students in the Alternatives Absent condition independently came up with the presented alternatives, and students in the Alternatives Present condition often did not address these alternatives in their questions, or came up with their own alternatives. Thus, it was possible to blind the rater to the Alternatives condition as well as the Explanation condition.

Table 2. Examples of Coding Schemata

Covariational Questions:
"Are there other areas where hawks are disappearing where there are no redwoods?" (examining influence on effect of the presence/absence of the primary cause)
"Does introducing mice into the environment increase the population of the hawk?" (examining influence on effect of the presence/absence of an alternate cause)

Noncovariational Questions:
"Do the hawks depend on the dwarf redwoods for nesting?" (a covariational version would be: "Is the number of hawk nesting sites decreasing with the decrease in dwarf redwoods?")
"Is their [hawks'] food source located in dwarf redwoods?" (a covariational version would be: "Is the amount of food available for hawks decreasing with the decrease in dwarf redwoods?")

Existence Questions:
"Does introducing mice into the environment increase the population of the hawk?" (covariational)
"How was this conclusion arrived upon?" (noncovariational)

Story Questions
"Does less trees mean less food?" (covariational)
"Do the red-crested hawks lay eggs in dwarf redwoods?" (noncovariational)

Questions addressing the primary claim

Sixty-six percent of questions addressed the primary claim. Explaining had the predicted undesirable effect (Tables 3 and 4). It caused a sharp rise questions addressing a particular Story ($F(1,60)= 9.25$, $p < 0.01$). Students were caught up in exploring their own particular story and failed to establish whether there was any relationship to explain. Explaining also resulted in a rise in Noncovariational questions

($F(1,60)=4.31$, $p < 0.05$); students were less likely to systematically lay out dimensions for testing. Thus, in the sound bite environment, explaining may be deleterious to reasoning.

Presenting alternatives was only partially successful in overcoming these problems. It did not prevent the shift toward Story questions ($F < 1$), but did encourage Covariational questions ($F(1,60)=10.27$, $p < 0.01$). We found no interaction between Explanation and Alternatives ($Fs < 1$). These alternatives were generally not part of the covariational comparison. That is, participants did not often suggest comparison that pit one claim against another, but rather the presence of the alternatives sharpened their tests of the primary claim on its own.

Table 3. Primary claim questions, coded with respect to information goals.

% of Story questions	Don't Explain	Explain
Alternative Absent	58.8%	78.5%
Alternative present	56.8%	75.8%

Table 4. Primary claim questions coded with respect to information type.

% of noncovariational questions	Don't Explain	Explain
Alternative Absent	53.9%	64.6%
Alternative Present	44.6%	48.7%

Questions addressing an alternative claim

Thirty-three percent of questions addressed alternatives, either presented or generated (Tables 5 and 6). Interestingly, students in the Alternative Present condition were no more likely to address alternatives than those in the Alternative Absent condition (34% vs. 32%). Explaining again caused an undesirable shift away from Existence questions ($F(1,58)=7.50$, $p < 0.01$), and away from Covariational questions, though this was only marginally significant ($F(1,58)=3.47$, $p=0.07$). We found no significant effects involving Alternatives, although the trend is towards presenting alternatives *aggravating* the effects of explaining. It may be that by addressing the alternative claim, it had effectively become the primary claim, and explaining thus had a negative effect.

Table 5. Alternative claim questions, coded with respect to information goals.

% of Story questions	Don't Explain	Explain
Alternative Absent	23.0%	36.3%
Alternative Present	32.6%	52.1%

Table 6. Alternative claim questions, coded with respect to information type.

% of noncovariational questions	Don't Explain	Explain
Alternative Absent	49.6%	55.0%
Alternative Present	47.7%	64.4%

Discussion

Overall, explaining works against a balanced consideration of Existence and Story goals, encouraging a search for noncovariational information that can be used to postulate responsible mechanisms. The presence of alternatives may preserve the search for covariational information after explaining for questions addressing the primary claim, but these searches are nevertheless directed towards finding a mechanism, rather than establishing the presence of a relationship to account for. In the case of questions addressing the alternative claim, the presentation of alternatives, if anything, worsened the situation.

It is also notable that only 33% of questions addressed alternatives, and presenting alternatives does not appear to have heightened students' awareness of other possibilities. This is consistent with previous studies showing that claims tend to be pursued in isolation (Mynatt, Doherty, Tweney & Schiavo, 1979), and that explaining reinforces this tendency (Koehler, 1991).

Overall, these results do not recommend using explaining as a strategy for filling gaps when evidence is lacking. Searching for a mechanism is not an error in itself; indeed, such a search is necessary to move from correlation to causation. Therefore, a shift to questions that serve Story goals may not be as problematic as a shift away from covariational questions. If no mechanism is found, perhaps the claim is wrong. However, this reasoning depends on students being able to exhaust the list of possible mechanisms—an unlikely scenario in any case, and certainly not the case when students ask only three questions. If an exhaustive search is not possible, the most efficient approach is to establish first that a relationship exists, and then to evaluate its causal potency. This makes the shift away from questions serving Existence goals troublesome.

More investigation regarding the effects of alternatives is called for. When students are focused on the primary goal, the presence of alternatives may have some benefit; students are not simply casting about for a mechanistic story, but are considering how they could test portions of that story. But ideally students will explore many possibilities, and when their focus switches from the primary, the benefits of presenting alternatives are lost. Furthermore, while alternatives produce less certainty in their wording, this does not appear to translate into a change in their information-seeking strategies. Understanding why this occurs may help use to determine the best way to structure students' explorations.

The motivation to look for explanations, even unsubstantiated explanations, has been well-documented as a common and spontaneous phenomenon (Ahn et al., 1995; Koehler, 1991; Brem & Rips, 1995; in press). While explanation had demonstrated potential as a tool in enhancing comprehension and problem-solving, it can also lead to less desirable strategies of inquiry. With greater understanding, we may be able to provide people with the tools they need to evaluate scientific issues accurately and confidently.

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