# The Role of Stated Relationships in Detecting Contradictions Between Multiple Representations in Science

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**Abstract:** The interpretation and evaluation of data presented in multiple sources is vital to the investigation of scientific phenomena in disciplinary authentic ways. This study investigated 8th graders (*N*=119) notice of contradictions between multiple representations (text and graph) when the relationship between variables was stated or inferred. Results suggest stating the relationship is related to identification of contradictions between representations. Results are discussed as they relate to the development of science disciplinary practices.

## Introduction

The ability to read and understand multiple representations is increasingly emphasized in educational research. This is especially true in the domain of science where being able to critically evaluate and compare multiple representations (e.g., text, table, graph, diagrams) is vital in order to investigate scientific phenomena in ways that are authentic to the practices of the domain (Ainsworth, 2008; Roth & Bowen, 2003; Wu & Krajcik, 2006). Accordingly, both science education professionals and educational standards emphasize the need for students to be able read and interpret data in different forms and use that information to be able to support and evaluate claims (Glazer, 2011; NGA & CCSSO, 2010). In order for students to critically evaluate a claim, it is important that they recognize discrepancies between the claim and the supporting data. However, research about the ways in which students interpret, evaluate and make decisions based on data presented in multiple forms is often disjointed and focuses primarily on texts. For example, there is evidence that students notice inconsistencies when reading totally verbal science texts and this is impacted by proximity of relevant information, source expertise and whether information is presented in single vs. multiple texts (Singer & Gagnon, 1999; Stadtler, Scharrer, Brummernhenrich & Bromme, 2013; Wiley & Myers, 2003). The degree to which students are capable of doing so when information is presented in visual versus verbal form is less clear. Accordingly, the current study investigated students' judgments of consistency between information presented in a verbal text and a graphic representation of that information. Specifically, we were interested in students' skills at recognizing whether a graph depicting a relationship provided in the verbal text did or did not match what was in the verbal text. We also manipulated whether this relationship was explicitly stated in the verbal text or had to be inferred by connecting information presented in the verbal text. We predicted that (a) students would be more likely to correctly identify a discrepancy between the graph and the text when the predicted relationship was explicitly stated than when it had to be inferred; and (b) descriptions of parts of the verbal text used to make the judgment would involve more parts of the verbal text when the relationship had to be inferred.

## Method

Participants in the study included 8th graders ($N$ = 119) attending 4 schools in the urban mid-west. We manipulated two variables within subjects: explicit versus inferred relationship and agreement between the graph and the verbal text (agrees vs. disagrees). Each participant saw 12 text/graph pairs (average number of words = 149.06), 4 of which were fillers and 8 of which were science topics (e.g., natural selection, the greenhouse effect, antibiotic resistance) Four sets of materials counterbalanced assignment of topic to the 4 explicitness x agreement conditions (2 topics per condition), and defined a between-subjects variable. Participants were asked to read each text, inspect the associated graph and answer two questions: 1) Using the information in the text, decide if this graph represents what we might expect to happen to [a variable in the specific topic] (response format: forced choice yes/no, and 2) What in the text did you use to make your decision? (response format: open-ended).

## Results

Forced choice yes/no responses were scored to indicate correct identification of text/graph contradiction or agreement. For example, if the graph contradicted the text and the participant indicated the graph contradicted the text they received a score of 1, yielding a maximum score of 2 per condition. Scores were analyzed using a 3-way mixed ANOVA with text explicitness and graph relationship as within-subjects factors and counterbalancing condition as a between subjects factor. Results show a main effect for text explicitness, $F(1, 115) = 17.15$, $p < .01$, partial $\eta^2 = .13$, such that scores were higher when the predicted relationship was stated ($M = .74$, $SD = .43$) than when the predicted relationship had to be inferred ($M = .61$, $SD = .48$). There was also

a main effect for graph relationship, $F(1, 115) = 98.11$, $p < .01$, partial $\eta^2 = .46$, such that the scores were higher when the graph agreed with the text ($M = .82$, $SD = .38$) than when the graph disagreed with the text ($M = .53$ $SD = .49$). There was no main effect for counterbalancing condition. There was a significant interaction between text explicitness and graph relationship, $F(1, 115) = 4.49$, $p < .05$, partial $\eta^2 = .04$. When the graph contradicted the text there was a difference between text explicitness, $F(1, 118) = 16.62$, $p < .01$, partial $\eta^2 = .12$ such that the score was higher when the predicted relationship was stated ($M = .63$, SD = .39) than when the predicted relationship had to be inferred ($M = .43$, $SD = .37$). However, when the graph was consistent with the text there was no effect of text explicitness. Additionally, although there was a three-way interaction among explicitness, relationship and counterbalancing condition ($F(3, 115) = 2.71$, $p = .05$, partial $\eta^2 = .07$), follow-up analyses indicated that the basic pattern of results was consistent for three of the four topic assignments to within-subjects condition. Open-ended responses to "what in the text did you use to make your decision?" were coded for number of different sentences indicated. Number of sentences cited was analyzed using a 2-way repeated measures ANOVA with text explicitness and graph agreement as within-subjects factors. Results indicated no main effects nor interactions, $F's$ $(1, 118) < 1$. Additionally, for texts where the relationship was explicitly stated, a paired samples t-test indicated no difference in participants' use of the stated relationship when the graph disagreed versus agreed with the verbal text, $t(118) = 1.71$, NS.

## Discussion and Future Work

The purpose of this study was to investiage students' consistency judgments between information presented in a verbal text and a graphic representation when the relationship between variables was explicitly stated or had to be inferred using multiple pieces of information in the text. Results indicate that 8th graders can identify contradictions between verbal text and graph, but are more likely to do so when the predicted relationship is explicitly stated. The lower detection rate for contradictions when the relationship is not stated may indicate that students do not always generate the inferences most appropriate to identify a mis-match between claims and supporting graphical representations of data. Furthermore, the lack of differences for the number of sentences cited may indicate that students are not recognizing which parts of the text are most relevant to evaluate data about scientific claims. On the other hand, we are currently examining whether there are differences related to condition in *which* information is selected. These deeper analyses will inform efforts to build learning contexts in which students generate inferences from stated information about relationships among variables. Ultimately the goal is to develop supports for students to be able to engage in critical evaluation of data in a way that is authentic to the disciplinary practice. Plans for future work include further investigation of the influence of topic, prior knowledge and grade level.

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