Learning with Diagrams: Effects on Inferences and the Integration of Information

Kirsten R. Butcher* and Walter Kintsch

University of Colorado, Boulder; Department of Psychology CB 345; Boulder, CO 80309
{kbutcher,wkintsch}@psych.colorado.edu

Abstract. Students studied materials about the human heart and circulatory system using either (a) text only, (b) text with simple diagrams, or (c) text with detailed diagrams. During learning, students self-explained [1] the materials. Explanations were transcribed, separated into propositions, and analyzed according to the type of learning process they represented. Results demonstrated that diagrams promoted inference generation but did not affect other learning processes (such as elaboration or comprehension monitoring). However, only simple diagrams promoted generation of inferences that integrated domain information. Results indicate that diagrams may be useful because they guide the learner to engage in the cognitive processes required for deep understanding.

1 Rationale and Experimental Approach

In recent years there has been growing interest and enthusiasm regarding the addition of visual resources to educational materials. The overall conclusion of previous research on text with pictures is that the addition of visual material improves students' memories and understanding [2]. In addition, Mayer and his colleagues have identified a number of principles that describe situations in which multimedia materials are most effective [3]. Although such principles are useful in identifying conditions that can maximize multimedia benefits, there is little evidence as to why diagrams improve memory and learning. The goals of this research were to determine: (a) if the comprehension processes of learners using text and diagrams were different from learners using text only, and (b) whether diagram complexity would influence comprehension processes.

A simple text about the heart and circulatory system was used alone or in conjunction with a series of diagrams from one of two types: diagrams that were simplified to emphasize the functional aspects of the heart (see Figure 1a), or more detailed diagrams that depicted the correct anatomy of the heart in addition to its functional aspects (see Figure 1b).

During learning, students self-explained the materials [1] and the resulting verbal protocols were separated into a series of complex propositions [4]. Two raters scored propositions as: paraphrases (statements that reflected information from the current

* Kirsten Butcher has moved to a joint appointment at the National Center for Atmospheric Research and the University Corporation for Atmospheric Research: UCAR Foothills Lab 4; Room #3304; P.O. Box 3000; Boulder, CO 80307-3000. kbutcher@ucar.edu

A. Blackwell et al. (Eds.): Diagrams 2004, LNAI 2980, pp. 337-340, 2004.

materials), elaborations (connections to prior knowledge), monitoring statements (utterances that demonstrated comprehension monitoring), or self-explanation inferences (statements that went beyond current materials or that integrated current and previous material). Because self-explanation inferences included multiple types of inferences, they also were separated into subcategories: path inferences (inferences that concerned the path of blood through the heart and circulatory system), nonpath inferences (inferences concerning content other than the path of blood), and integration inferences (inferences that connected current and previous information; these included path or nonpath inferences that integrated information). Interrater reliability ranged between .70 and .99 (M = .88). Additional work assessed students' mental models of the domain and the relationship between inference generation and mental model development [5]. Students drew and explained the heart and circulatory system before and after learning; these materials allowed mental model assessment and were scored for accuracy according to criteria from Chi et al. [1].

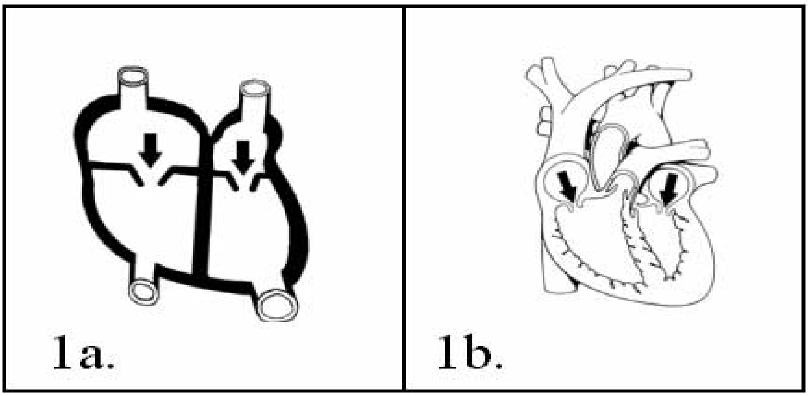

Fig. 1. (1a) A simple diagram emphasizing functional relations. (1b) A detailed diagram preserving anatomical accuracy

2 Results

As seen in Fig. 2., students using either type of diagram made significantly more self-explanation inferences than students using text only ($F_{(2,22)} = 9.3$, $p < .01$), but did not differ in the number of other propositions uttered ($F < 1$).

Students using either diagram also made significantly more path ($F_{(2, 22)} = 5.0$, $p < .02$) and nonpath inferences ($F_{(2, 22)} = 8.3$, $p < .01$) than students who used text only; however, only path inferences were tied to formation of the correct mental model of the domain. Students who formed the correct mental model of the domain made significantly more path inferences during learning than students who failed to form the correct model ($F_{(1, 23)} = 5.0$, $p < .04$). Path inferences may be related to mental animation processes; diagram cues could prompt mental animation and allow the student to draw path inferences. Current results suggest diagrams promote inference generation and some inferences support mental model development.

Finally, integration inferences demonstrated an interesting pattern. Students who saw simple diagrams generated more integration inferences ($F_{(2, 22)} = 4.9$, $p < .02$) than students using text only (*M* difference = 17.5, *LSD* = 11.9, $p < .01$) and also tended to generate more of these inferences than students using detailed diagrams (*M* difference = 11.0, *LSD* = 11.5, $p = .06$). As with path inferences, students who formed the correct mental model of the domain generated significantly more integration inferences than students who failed to form the correct model ($F_{(1, 23)} = 6.1$, $p < .03$). Thus, not all diagrams support comprehension processes equally.

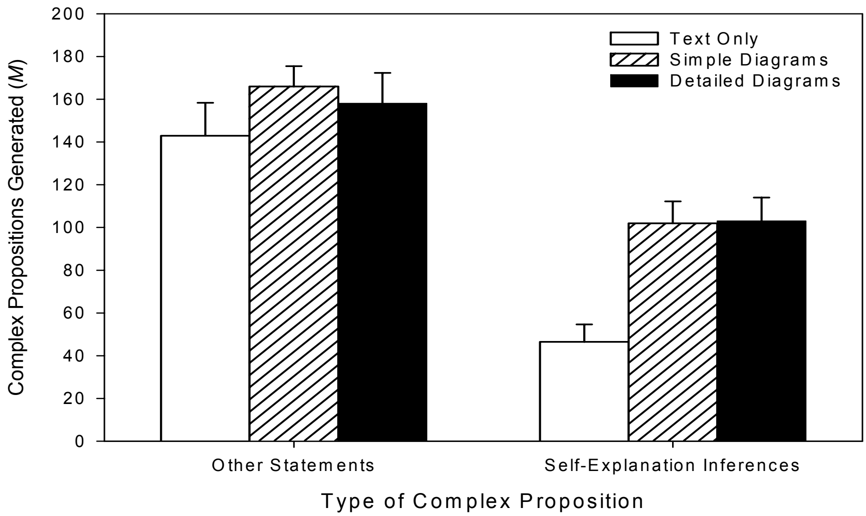

Fig. 2. Mean number (+Standard Error) of other statements and self-explanation inferences generated by students in each experimental condition

3 Conclusion

This research suggests that diagrams are effective when they prompt learners to engage in the cognitive processes necessary for deep understanding. Results also demonstrated that differences in diagram representation can affect comprehension processes. In this situation, simple diagrams most effectively guided learners. However, one must be careful not to misinterpret this finding. In other situations, different types of diagrams or visual cues may be effective if they successfully prompt inference generation without adversely affecting other processes.

References

[1] Chi, M. T., de Leeuw, N., Chiu, M.-H. & LaVancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive Science, 18,* 439-477.

[2] Carney, R. N. & Levin, J. R. (2002). Pictorial illustrations *still* improve students' learning from text. *Educational Psychology Review, 14,* 5-26.

[3] Mayer, R. E. (2001). *Multimedia Learning*. Cambridge: Cambridge University Press.

[4] Kintsch, W. (1998). *Comprehension: A paradigm for cognition*. Cambridge: Cambridge University Press.

[5] Butcher, K. R. (2003). Effects of diagram complexity on comprehension processes and learning outcomes. Unpublished doctoral dissertation: University of Colorado, Boulder. Available online: http://psych.colorado.edu/~kbutcher/