The Effects of Representational Bias on Collaborative Inquiry

Daniel D. Suthers
Department of Information and Computer Sciences
University of Hawai'i at Manoa
1680 East West Road POST 303A
Honolulu HI 96822
suthers@hawaii.edu

1 Introduction

For a number of years, the author and his colleagues (see acknowledgments) have been building, testing, and refining a diagrammatic environment intended to support secondary school children's learning of critical inquiry skills in the context of science (Suthers et al 1997). During this time, a refocus on *collaborative* learning led to a major change in how we viewed the role of the interface representations. Rather than being a medium of communication or a formal record of the argumentation process, we came to view the representations as resources for conversation (Roschelle 1994).

These observations, coupled with the fact that other projects with similar goals were using radically different representational systems, led the author to propose a more systematic study of the ways in which these different representational systems can influence collaborative learning discourse. The differences in representational notations that are provided by existing software for critical inquiry are striking. The range includes hypertext/hypermedia systems (Guzdial, et al. 1997, O'Neill & Gomez 1994, Scardamalia et al. 1992), argument mapping environments (Ranney et al. 1995, Smolensky et al 1987, Suthers et al 1997), containment representations (Bell 1997), and matrices (Puntambekar et al. 1997). Yet there is a lack of systematic studies *comparing* the effects of external representations on collaborative learning discourse. Given that these representations define the fundamental character of software intended to guide learning, a systematic comparison is overdue.

Substantial research has been conducted concerning the role of external representations in individual problem solving, generally showing that the kind of representations used to depict a problem may influence problem solving efficiency (Kotovsky & Simon 1990, Larkin & Simon 1987, Zhang 1997). One might ask whether this research is sufficient to predict the effects of representations in collaborative learning. A line of work undertaken in collaborative learning contexts is needed because the interaction of the cognitive processes of several agents is different than the reasoning of a single agent (Perkins 1993), so may be affected by external representations in different ways. Shared external representations can be used to coordinate distributed work, and will serve this function different ways according to their representational biases. Also, the mere presence of representations in a shared context with collaborating agents may change each individual's cognitive processes. One person can ignore discrepancies between thought and external representations, but an individual working in a group must constantly refer back to the shared external representation while coordinating activities with others.

2 Hypothesized Effects of Representational Bias

Representational tools are artifacts (such as software) with which users construct, examine, and manipulate external representations of their knowledge. A representational tool is an implementation of a *representational notation* that provides a set of primitive elements out of which representations can be constructed. Developers choose a representational notation and instantiate it as a representational tool, while the user of the tool constructs particular *representational artifacts* in the tool. The present analysis focuses on interactions between learners and other learners, specifically verbal and gestural interactions termed *collaborative learning discourse.*

Each given representational notation manifests a particular *representational bias,* expressing certain aspects of one's knowledge better than others do (Utgoff 1986). Representational bias manifests in two major ways: *Constraints:* limits on logical expressiveness; and *Salience:* how the representation facilitates processing of certain knowledge units, possibly at the expense of others. Representational tools mediate collaborative learning discourse by providing learners with the means to articulate emerging knowledge in a persistent medium, inspectable by all participants, where the knowledge then becomes part of the shared context. Representational bias *constrains* the knowledge that can be expressed in the shared context, and makes some of that knowledge more *salient* and hence a likely topic of discussion.

Stenning and Oberlander (1995) distinguish constraints inherent in the logical properties of a representational notation from constraints arising from the architecture of the agent using the representational notation. This corresponds roughly to the present author's distinction between "constraints" and "salience." Constraints arise from logical limits on the information that can be expressed in the representational notation, while salience arises from how easily the agent recovers the information (via perception) from the representational artifacts.

Information that is recoverable from a representation is salient to the extent to which it is recoverable by automatic perceptual processing rather than through a controlled sequence of perceptual operators (Zhang 1997).

2.1 Notations have Ontological Bias

The first hypothesis claims that important guidance for collaborative learning discourse comes from ways in which a representational notation *limits* what can be represented (Reader unpublished, Stenning & Oberlander 1995). A representational notation provides a set of primitive elements out of which representational artifacts are constructed. These primitive elements constitute an "ontology" of categories and structures for organizing the task domain. Learners will see their task in part as one of making acceptable representational artifacts out of these primitives. Thus, they will search for possible new instances of the primitive elements, and hence (according to this hypothesis) will be biased to think about the task domain in terms of the underlying ontology.

2.2 Salient Knowledge Units are Elaborated

This hypothesis states that learners will be more likely to attend to, and hence elaborate on, the knowledge units that are perceptually salient in their shared representational workspace than those that are either not salient or for which a representational proxy has not been created. The visual presence of the knowledge unit in the shared representational context serves as a reminder of its existence and any work that may need to be done with it. Also, it is easier to refer to a knowledge unit that has a visual manifestation, so learners will find it easier to express their subsequent thoughts about this unit than about those that require complex verbal descriptions (Clark & Brennan 1991). These claims apply to any visually shared representations. However, to the extent that two representational notations differ in kinds of knowledge units they make salient, these functions of *reminding* and *ease of reference* will encourage elaboration on different kinds of knowledge units.

2.3 Salience of Missing Units Guides Search

Some representational notations provide structures for organizing knowledge units, in addition to primitives for construction of individual knowledge units. Unfilled "fields" in these organizing structures, if perceptually salient, can make missing knowledge units as salient as those that are present. If the representational notation provides structures with predetermined fields that need to be filled with knowledge units, the present hypothesis predicts that learners will try to fill these fields.

3 Empirical Studies

The author has begun studies that test the effects of representational notations on collaborative discourse and learning. Subjects are presented with a "science challenge problem" in a web-browser. A science challenge problem presents a phenomenon to be explained, along with indices to relevant resources. These are relatively ill-structured problems: at any given point many possible knowledge units may reasonably be considered. One side of the computer screen contains the representational tool, such as Threaded Discussion, Containment, Graph, or Matrix. The other side contains a web browser open to the entry page for the science challenge materials. Students seated in front of the monitor are asked to read the problem statement in the web browser. They are then be asked to identify hypotheses that provide candidate explanations of the phenomenon posed, and evaluate these hypotheses on the basis of laboratory studies and field reports obtained through the hypertext interface. They are asked to use the representational tool to record the information they find and how it bears on the problem. Analysis is based on transcripts of subjects' spoken discourse, gestures, and modifications to the interface; as well as measures of learning outcomes. A pilot study was conducted comparing MS Word (unstructured text), MS Excel (tables), and Belvedere (graphs), with two pairs of subjects run in each condition. The data is currently under analysis. Preliminary results are encouraging, and will be presented at the conference.

4 Acknowledgments

The author is grateful to Micki Chi, Martha Crosby, and John Levine for discussions concerning the role of representations in learning, visual search, and social aspects of learning, respectively; to LRDC colleagues Alan Lesgold, Eva Toth, Arlene Weiner for collaborations on Belvedere; and to Cynthia Liefeld for assistance with the pilot studies. This work was funded by DoDEA's Presidential Technology Initiative and by NSF's Learning and Intelligent Systems program.

5 References Cited

Bell, P. (1997). Using argument representations to make thinking visible for individuals and groups. In Proc. Computer Supported Collaborative Learning '97, pp. 10-19. University of Toronto, December 10-14, 1997.

Clark, H.H. & Brennan, S.E. (1991). Grounding in Communication. In L.B. Resnick, J.M. Levine and S.D. Teasley (eds.), *Perspectives on Socially Shared Cognition*, American Psychological Association, 1991, pp. 127-149.

Guzdial, M., Hmelo, C., Hubscher, R., Nagel, K., Newstetter, W., Puntambekar, S., Shabo, A., Turns, J., & Kolodner, J. L. (1997). Integrating and guiding collaboration: Lessons learned in Computer-Supported Collaborative Learning research at Georgia Tech. *Proc. 2nd Int. Conf. on Computer Supported Collaborative Learning (CSCL'97)*, Toronto, December 10-14, 1997. pp. 91-100.

Kotovsky, K. and H. A. Simon (1990). "What makes some problems really hard: Explorations in the problem space of difficulty." *Cognitive Psychology* 22: 143-183.

Larkin, J. H. & Simon, H. A. (1987). Why a diagram is (sometimes) worth ten thousand words. *Cognitive Science 11(1):* 65-99. 1987.

O'Neill, D. K., & Gomez, L. M. (1994).The collaboratory notebook: A distributed knowledge-building environment for project-enhanced learning. In *Proc. Ed-Media '94*, Vancouver, BC.

Perkins, D.N. (1993). Person-plus: A distributed view of thinking and learning. In *G. Salomon (Ed). Distributed cognitions: Psychological and Educational Considerations* pp. 88-111.Cambridge: Cambridge University Press.

Puntambekar, S., Nagel, K., Hübscher, R., Guzdial, M., & Kolodner, J. (1997). Intra-group and Intergroup: An exploration of Learning with Complementary Collaboration Tools. In *Proc Computer Supported Collaborative Learning Conference '97*, pp. 207-214. University of Toronto, December 10-14, 1997.

Ranney, M., Schank, P., & Diehl, C. (1995). Competence versus performance in critical reasoning: Reducing the gap by using Convince Me. *Psychology Teaching Review, 1995, 4(2).*

Reader, W. (Unpublished). Structuring Argument: The Role of Constraint in the Explication of Scientific Argument, manuscript dated November 1997.

Roschelle, J. (1994). *Designing for Cognitive Communication: Epistemic Fidelity or Mediating Collaborative Inquiry?* The Arachnet Electronic Journal on Virtual Culture, May 16, 1994. Available: ftp://ftp.lib.ncsu.edu/pub/stacks/aejvc/aejvc-v2n02-roschelle-designing

Scardamalia, M., Bereiter, C., Brett, C., Burtis, P.J., Calhoun, C., & Smith Lea, N. (1992). Educational applications of a networked communal database. *Interactive Learning Environments*, 2(1), 45-71.

Smolensky, P., Fox, B., King, R., & Lewis, C. (1987). Computer-aided reasoned discourse, or, how to argue with a computer. In R. Guindon (Ed.), Cognitive science and its applications for human-computer interaction (pp. 109-162). Hillsdale, NJ: Erlbaum.

Stenning, K. & Oberlander, J. (1995). A cognitive theory of graphical and linguistic reasoning: Logic and implementation. *Cognitive Science 19(1):* 97-140. 1995.

Suthers, D., Toth, E., and Weiner, A. (1997). An Integrated Approach to Implementing Collaborative Inquiry in the Classroom. *Proc. 2nd Int. Conf. on Computer Supported Collaborative Learning (CSCL'97)*, Toronto, December 10-14, 1997. pp. 272-279.

Utgoff, P. (1986). Shift of bias for inductive concept learning. In *R. Michalski, J. Carbonell, T. Mitchell (Eds.) Machine Learning: An Artitificial Intelligence Approach, Volume II*, Los Altos: Morgan Kaufmann 1986, pp. 107-148.

Zhang, J. (1997). The nature of external representations in problem solving. *Cognitive Science*, 21(2): 179-217, 1997.