Collaborative Dialog While Studying Worked-out Examples

Robert G.M. HAUSMANN[1], Timothy J. NOKES[1],
Kurt VANLEHN[2], and Brett VAN DE SANDE[2]
[1]*Learning Research and Development Center, Pittsburgh Science of Learning Center*
University of Pittsburgh, 3939 O'Hara Street, Pittsburgh, PA, 15260
[2]*School of Computing and Informatics, Ira A. Fulton School of Engineering*
Arizona State University, P.O. Box 878809, Tempe, AZ 85287 - 8809

Abstract. Self-explaining is a beneficial learning strategy for studying worked-out examples because it either supplies missing information through the generation of inferences or because it provides a mechanism for repairing flawed mental models. Although self-explanation is generated with the purpose of helping the individual, is it also helpful to produce explanations in a collaborative setting? Can individuals help each other infer missing information or repair their flawed mental models collaboratively? To find out, we coded the dialog from dyads collaboratively studying examples and contrasted it with individuals studying examples alone. The results suggest that dyads were more likely to attempt to reconcile the examples with their attempted solutions, and avoid shallow processing of examples through paraphrasing.

Keywords. Self-explanation, peer collaboration, prior knowledge, physics

Introduction

Although studying solutions to problems can facilitate learning, there is always the danger that students will study these examples shallowly and not learn much. One way to increase the effectiveness of learning from examples is to prompt students to self-explain each step [1]. Another way is to alternate examples with problem solving [2]. A third possibility is to have students work together in dyads while studying examples. We hypothesized that the participants working in dyads would have an opportunity to engage in a wider range of constructive cognitive processes than they would when explaining examples alone. Consistent with other research on collaboration, we found that the dyads (at the group level) learned more from studying examples than solos as measured by problem-solving performance [3]. The purpose of the current work is to investigate and unpack the cognitive processes underlying this advantage.

In the experiment, our baseline condition was solos who were prompted to self-explain examples that alternated with problem solving on the Andes tutoring system. Our experimental group was dyads who did the same activities as solos. Because the main (positive) result has already been published [3], this paper focuses on contrastive analyses of the protocols aimed at finding out *why* the dyads learned more than the solos.

1. Experimental Context and Coding the Verbal Protocols

Undergraduates enrolled in a second semester physics course were randomly assigned to either the Solo (n = 11) or Dyad (n = 14) condition. During the experiment, the students were asked to alternate between solving electrodynamics problems in Andes and studying video-based, isomorphic examples. The data for example studying consisted of coding the transcribed monolog or dialog generated by the participants.

To summarize the relevant findings from the experiment, the solos solved fewer problems during the fixed, two-hour training period; the solos asked for more hints and bottom-out hints when solving problems; and they made more deep errors than the dyads [3]. This suggests that the dyads were more effective in solving the problems. To better understand the problem-solving results, the verbal protocols collected during the example-studying phase of the experiment were analyzed by categorizing the verbalizations. Each of the four categories are defined in Table 1.

Table 1. Definitions for the coarse-grained coding scheme

Code	Definition
Explain	Typically, an explanation is an answer to the question *why*? In addition, explanations identify the applicability conditions of a rule.
Prior	Relates an example step to any of the following: work on prior problems in the experiment (either noting similarities or differences), or background knowledge from physics course.
Meta-cognitive	A positive or negative assessment regarding one's understanding of the material.
Paraphrase	A restatement of the given information. The restatement can be a verbatim repetition of the information, the information stated in slightly different words, or a summary.

Because the dyads naturally generated more dialog than the solos ($F(1, 20) = 6.18$, $p < .05$, $d = 1.11$), all of the subsequent analyses statistically controlled for the overall number of coded statements using an analysis of covariance (ANCOVA). The results for all four categories of coded dialog are reported in

Figure **1**.

While controlling for the total amount of talk, there was no difference between the two conditions in terms of the number of explanations produced, $F < 1$. However, there was a marginal, negative correlation between the number of explanation statements and the error rate for the dyad condition, $r(10) = -.57$, $p = .06$. The same negative correlation, however, was not true for the solo condition. This suggests that the explanations generated by the dyads helped them to avoid errors on later problems, whereas the explanations of the solos were remarkably unhelpful.

For the other categories, there were reliable differences between the two groups in terms of the amount of paraphrasing and use of prior knowledge. The solo condition (M = 27.00, SE = 4.71) produced more paraphrases than the dyad condition (M = 7.74, SE = 4.25), $F(1, 19) = 8.14$, $p < .05$, $d = -.63$. This result suggests that the solos were more likely than the dyads to use paraphrasing as a method for studying the examples. Because paraphrasing tends to produce less learning than self-explanation [4], the main results (i.e., the solos learned less than dyads) may be in part due to the solos choosing to do more shallow processing (i.e., paraphrasing) of the examples than the dyads.

The pattern of means was the opposite for the use of prior knowledge. The dyad condition (M = 33.65, SE = 4.23) demonstrated a greater number of prior knowledge episodes than the solo condition (M = 18.92, SE = 4.69). The difference in the dyads' explicit use of prior knowledge was both statistically significant, with a large effect size, $F(1, 19) = 4.81$, $p < .05$, $d = 1.60$. This may represent another contribution to the dyads' superior learning, as more reference to prior knowledge is often associated with larger learning gains [5].

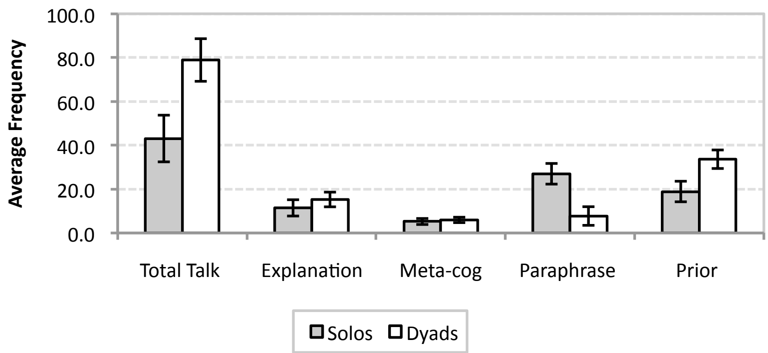

Figure 1. The estimated marginal means (± standard error bars) for the frequency of each type of statement.

2. Discussion

The current "state of the art" in studying examples suggests that one should have students alternate between studying an example and solving a problem [2]. When studying the example, students should be prompted to self-explain [1]. We have shown that further benefits can be obtained by having students do these activities in pairs rather than alone [3]. This paper presented evidence from protocol analyses that point toward a potential source of this extra benefit. It appears that the solos are spending more time on paraphrasing the example, a type of shallow processing associated with reduced learning [4]. In contrast, the dyads more frequently compared the example's solution with their solutions during the preceding problem solving [6]. This led to better problem-solving performance with an intelligent tutoring system.

References

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

[2] Trafton, J.G., Reiser, B.J.: The contributions of studying examples and solving problems to skill acquisition. Proceedings of the Fifteenth Annual Conference of the Cognitive Science Society. Erlbaum, Hillsdale, NJ (1993) 1017-1022

[3] Hausmann, R.G.M., van de Sande, B., VanLehn, K.: Shall we explain? Augmenting learning from intelligent tutoring systems and peer collaboration. In: Woolf, B.P., Aimeur, E., Nkambou, R., Lajoie, S. (eds.): Intelligent Tutoring Systems. Springer-Verlag, Berlin (2008) 636–645

[4] Chi, M.T.H., Bassok, M., Lewis, M.W., Reimann, P., Glaser, R.: Self-explanations: How students study and use examples in learning to solve problems. Cognitive Science **13** (1989) 145-182

[5] Bransford, J.D., Brown, A.L., Cocking, R.R. (eds.): How people learn: Brain, mind, experience, and school. National Academy Press, Washington, D.C. (2000)

[6] Nokes, T.J., VanLehn, K.: Bridging principles and examples through analogy and explanation. In: Kirschner, P.A., Prins, F., Jonker, V., Kanselaar, G. (eds.): Proceedings of the Eighth International Conference for the Learning Sciences -- ICLS 2008, Vol. 3. ISLS, The Netherlands (2008) 100-102