

# How Representation Matters: Comparing Collaborative Learning with Alternative Versions of Hypermedia

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**Abstract.** The goal of this comparative case study is to investigate how students collaboratively learn about complex systems with hypermedia. This study also investigates how the conceptual representation underlying the hypermedia influences students' collaborative activities and knowledge co-construction. We use two different types of hypermedia to study the human respiratory system. One version of the hypermedia highlights the structural and the second version the functional-behavioral aspects of the human respiratory system. An in-depth analysis of two dyads, working on two versions of the hypermedia, will be presented in this paper.

**Keywords:** Knowledge co-construction, conceptual representation, hypermedia

## INTRODUCTION

Concrete external representations can profoundly affect discourse (Suthers & Hundhausen, 2002) but there has not been any research that explores the role of *conceptual* representations on collaborative learning. Conceptual representations are often implicit in learning resources such as hypermedia and can be used to guide the learning process and alter the course of collaborative learning conversations (Suthers & Hundhausen, 2002). Prior research has shown that hypermedia can be an effective representational aid for individual understanding and problem solving (Jacobson & Archididou, 2000). The research reported in this paper addresses the question of how conceptual representations embodied in hypermedia have the potential to guide and support knowledge co-construction as we explore the effects on collaborative learning processes. In this paper, we present an analysis of two dyads working on two different versions of hypermedia.

## THEORETICAL RATIONALE

Collaborative learning provides opportunities for learners to engage in constructive processing. Computer-based instructional systems, such as hypermedia, provide an opportunity for learners to develop shared conceptual understanding.

Research on peer collaboration suggests that students profit from peer interactions especially from communicative exchanges (Rogoff, 1990). Peer interactions may contribute to intentional conceptual change by arousing an awareness of the need for revision of knowledge, a very critical step towards conceptual change. The resultant disequilibrium might lead up to final conceptual change via integrating old and new knowledge.

The fact that computers can play an important role as representational aids for learning is well established (Kozma, 2000). Dynamic and visual computer-based instructional systems mediate learning through nonlinear and vivid representations (Hegarty, Narayanan & Freitas, 2002).

In addition to the diagrammatic representations, computers can also be used as conceptual representational tools that characterize expert understanding of a domain (Pea, 1993). We are particularly interested in how people understand complex systems and the conceptual representations that underlies expertise in complex systems domains. Complex causal systems can be represented in a number of different ways. We use structure-behavior-function (SBF) theory as the underlying conceptual representation to design hypermedia for instruction.

The SBF representation allows effective reasoning about the functional and causal roles played by structural elements in a system and helps in understanding how different levels of a complex causal system interact (Goel et al., 1996). Expert-novice comparisons in two complex system domains have demonstrated that novices tend to attend to structure and have little understanding of the functional and behavioral aspects of complex systems (Hmelo-Silver, 2004). Moreover, novices tend to understand salient aspects of a system. On the other hand, expert understanding is a coherent representation of structures, behaviors and functions. In current study, we propose that, to foster deep understanding, instruction needs to make function and behaviors salient.

We designed two versions of the hypermedia system: a function-centered and a structure-centered version. The function-centered hypermedia emphasizes the interrelationships within a system. This conceptualization is nonlinear and closer to experts' mental models. Like traditional textbooks, a structure-centered hypermedia should cause students to focus on structure and miss the connectedness within the system. A study comparing these two versions on individual learning has shown that students in the function-centered condition had better

understanding of non-salient structures, functions, and behaviors of human respiratory system, such as cellular respiration, than students in the structure-centered condition. We followed up with a qualitative study to investigate how two dyads understand the human respiratory system with two different computer representations, namely the function-centered and structure-centered hypermedia.

## METHOD

### Participants

We enrolled 4 participants, grouped into 2 dyads from the educational psychology subject pool at a large public university. Each participant received course credits for participating in the study. All the participants were female.

### Procedure

The first author ran the study with each dyad. The session was videotaped using two cameras. One of the video cameras was focused on the screen to capture what the dyad was viewing; the other one was focused on the two students. One dyad was randomly assigned to use the function-version of the hypermedia (F-dyad), the other to the structure-centered hypermedia (S-dyad). Each used their version of the hypermedia to learn about the human respiratory system. All the procedures were otherwise exactly the same for both dyads.

All participants were asked to take a pretest on the human respiratory system before starting to explore the hypermedia. After the pretest, the experimenter instructed the participants to explain to their partner what the content meant to them and how it related to what they already knew about the human respiratory system. Afterwards, the dyads were informed that they needed to explore the hypermedia system for approximately 40 minutes. After using the system, all participants completed a posttest on their conceptual understanding. All participants also completed a questionnaire on their attitude towards using the software and the collaborative learning activities.

### Materials

The two different versions of hypermedia emphasized different conceptual representations. The function-centered version of hypermedia had the information organized around functions and behaviors of the components in the system. Learners using the function-centered version first viewed the two major functional-behavioral questions, which led them to explore the function of the whole system first, as shown on the left in Figure 1. Then they studied respective behaviors and structures. Alternatively, the structure-oriented version organized information around the structures of the system. Learners started with a diagram of the human respiratory system with links to each component in the system. Then they studied their behaviors and functions. Except for the different underlying conceptual representations that were used to organize the information, the two versions of hypermedia shared identical content. Figure 1 display the two different opening screens.



Figure 1. Opening screens of the function-oriented and the structure-oriented hypermedia.

### Coding and Analysis

The tapes were transcribed verbatim blind to condition. The transcriptions were coded in three passes. The first pass was to divide the conversation into episodes marked by switches in the topic of a discussion. This was accomplished by reviewing the videotapes and identifying the screens that were being viewed. Screens on a specific topic, such as cellular respiration, lungs, transporting, were grouped as one episode.

In the second pass, each episode was coded into segments that consisted of five different discourse functions: social talk, task talk, reading, quizzing and negotiation. Social talk served to establish common ground or to allow the partners to become familiar, for example "Are you in Educational Psychology?" Task talk was about

how learners would navigate the hypermedia, for example, “Should I click on this?” A reading episode involved verbatim reading of the text on the screens. Quizzing occurred as the students tested each other’s learning. Finally, a negotiation episode was when the students attempted to share understanding and construct meaning.

In the final pass through transcripts, we focused on negotiation segments and identified discussions of prior knowledge, paraphrasing, elaboration/articulation, asking and answering questions (classified into structure, behavior and function questions), agreement, disagreement, metacognition, and talking about salient components vs. non-salient components of the system. All but the last categories are indicators of constructive processing and are associated with learning (Chi et al., 2001). The last category was coded because it was found in our previous research that novices regularly notice salient aspects and poorly understand nonsalient aspects, which are particularly important for a deep understanding of the system.

## RESULTS

Both transcriptions were marked with conversational turns and words were counted. In the F-dyad’s transcription, there were 250 turns and 2895 words in total. S-Dyad had 288 turns and 2333 words. Table 1 presents the segment number and percentage of each discourse function of both dyads.

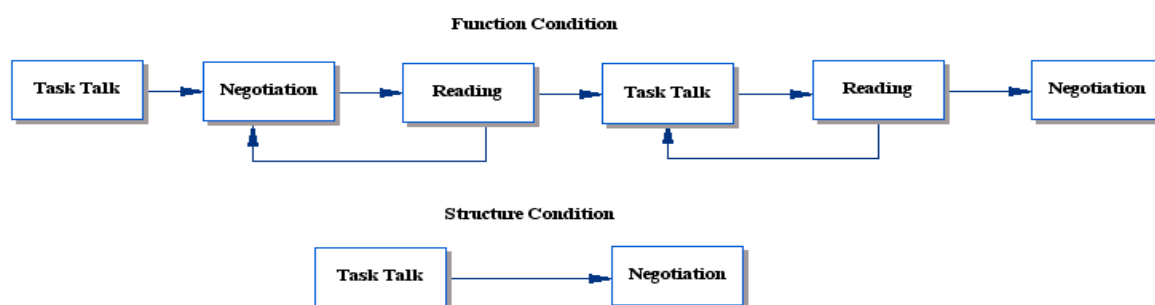
*Table 1. Distribution of discourse segments in both conditions.*

Discourse Function	F-dyad	S-dyad
Social Talk	1 (1.3%)	5 (8.06%)
Task Talk	22 (28.57%)	26 (41.94%)
Reading	29 (37.66%)	18 (29.03%)
Quizzing	0 (0%)	1 (1.61%)
Negotiation	25 (32.47%)	12 (19.35%)
Total	77	62

Findings of an in-depth analysis of the dyads’ collaborative discourses will be discussed in two main areas: sequence of episodes and knowledge negotiated.

### Sequence of Episodes

During the first pass, we found some differences in the sequence of segments across the two conditions as shown in Figure 4. Another difference we observed is that, F-dyad engaged in more complicated sequences of the discourse functions compared to the S-dyad. For example, Figure 4 shows the sequences of segments on the topic of intercostals muscles in the two conditions. In particular, we focused on where the negotiation segments occurred in relation to other segments including social talk, task talk, and reading. We found that F-dyad engaged in the most negotiated episodes. In contrast, there was no such negotiation in S-dyad’s discourse.



*Figure 4. Sequences of segments on the topic of intercostal muscles.*

### Knowledge Negotiated

During the second and third passes through the data, we focused on what kind of knowledge had been negotiated among dyads and how this occurred. The following sections display our findings from three aspects: the kind of knowledge negotiated, types of questions that arose in negotiation, and the process of knowledge co-construction.

#### *Nonsalient vs. Salient Knowledge*

Consistent with our previous results (Hmelo-Silver, 2004), the F-dyad engaged in more discussion about non-salient phenomena. All the long negotiation segments occurred when the F-dyad discussed non-salient topics, such as cellular respiration, diffusion (functions of alveoli and capillaries), and how the vascular system works. But they did conduct a long negotiation when exploring the function of the diaphragm in the human respiratory

system, a typical salient phenomenon. In addition, after completing navigation of the whole system with the function-behavior oriented hypermedia, F-dyad reviewed two topics on which they were still confused: the function of red blood cells and capillaries, both of which are non-salient but very essential phenomena in the human respiratory system. The following excerpt comes from this discussion:

- Amy: But we still haven't found out about the red blood cells?  
Maggie: Oh, yeah.  
...  
Maggie: Well, usually blood cells, just kind of, I know, they are in the blood, but maybe they are just help carrying...  
Amy: I thought blood cells, mm..., like protect our body from like...  
Maggie: I think, Oh, like immunization?... I think that's white blood cells. But I am not sure... cause my sister was sick a long time ago, and they are always monitoring her white blood cells... but maybe there is red blood cells too. I don't know.  
Amy: (searching the hypermedia) Oh... Maybe are any of those?  
Maggie: (pointing at the screen) So they go out? Oh, that's oxygen.  
Amy: Maybe red blood cells carry oxygen, but I am not sure.  
Maggie: It kind of looks like the oxygen was getting replaced by carbon dioxide in the red blood cells...  
Amy: Oh, yeah?  
Maggie: So maybe that's ... Oh, wait ... wait, why does it say carbon dioxide and oxygen?  
Anne: I don't really know. It feels like how carbon dioxide goes in there but it looks like it's going out there.  
Maggie: Oh, I bet because they are talking about capillaries and exchanging stuff.  
Amy: Oh, maybe that is when the whole, when the blood goes into the alveoli, whatever, and then it gives out oxygen, and then when it goes, what was that one part that we were having trouble with in the beginning?  
Maggie: With the capillaries?  
Amy: Yeah!

In contrast, the S-dyad's negotiations were very short. In addition, most of the negotiation episodes concerned salient topics. The following is a typical example of how the S-dyad engaged in negotiation when they discussed the red blood cells. Clearly, they are engaging in less elaboration and the behavior (diffusion) remains a black box.

- Susan: So there is lungs, alveoli or whatever, and they bring out ...  
Lisa: They diffuse it ...  
Susan: Into the blood, ok, diffuse it into the blood.

### *Behavior vs. Structure Questions*

Another difference between two conditions lies in the questions that the dyads asked during the negotiation segments. Specifically, the F-dyad raised more questions and these were likely to be questions about system behaviors. F-dyad participants focused their discussions on "how" and "why" questions. In addition, their negotiations were mainly directed towards solving the problems they encountered when reading the hypermedia content. Driven by those questions and their knowledge limitations, the F-dyad spent most of their time in purposeful exploration of the hypermedia. For instance, in turn 50, Maggie asked "... do the capillaries take it (the blood) to the blood vessels or...?", and "How does it (the air) get there?" in turn 132. Amy also led several behavior-driven discussions. For example, in turn 86, Amy asked "what is it like, pushed out through the lungs first and then pushed out to the body, like ... as it pumps or no?"

In contrast, the S-dyad asked fewer questions about structures. The few questions they proposed as well as the quizzing segments were mainly structure-oriented which was consistent with the conceptual organization of the hypermedia they explored. In comparison to the F-dyad, the exploration of the hypermedia by the S-dyad seemed to be aimless and lacked goals. It is also found that most of their navigational choice did not show a clear purpose. The S-dyad typically went to the main page first, and then selected the links to topics they had not yet viewed. In summary, the F-dyad seemed more motivated by the gaps in their understanding than the S-dyad.

### *Knowledge Co-constructed*

In our third pass of coding, we analyzed what was been co-constructed by both dyads and how the knowledge was shared. The dyads took different approaches to co-construct knowledge or questions that would focus their efforts on sense-making. For instance, in turns 61-71, the F-dyad tried very hard to reach a shared understanding. At first, both Maggie and Amy expressed their confusion about the behaviors of capillaries. Before looking for the answer in the hypermedia, Maggie vaguely explained the behavior based on her own understanding. After searching for and reading the content on the page introducing the behavior of capillaries, Amy agreed with Maggie's previous explanation. Thus, Maggie and Amy reached shared knowledge through a

combined processing of self-explanation (Chi et al., 1994) and searching for evidence to support an explanation. In addition, they also co-constructed the recognition of one unsolved question: what the relationship between capillaries and other components in the respiratory system is. Compared to the F-dyad, the S-dyad students realized that there was some confusion in their understanding, but they did not try to answer those questions. Since the S-dyad students did not persist in pursuing the questions, they showed little evidence of co-constructed knowledge during the collaborative interactions.

## DISCUSSION AND CONCLUSIONS

Our results suggest that, like diagrammatic representations, conceptual representations affect how students co-construct knowledge. This comparative case study demonstrated that when students learned from a function-oriented hypermedia, they engaged in more constructive processing as well as discussing those aspects of the system that are typically difficult to understand—the nonsalient aspects. Although the function-oriented hypermedia seemed more difficult for the students to understand, it seemed to afford more opportunities for the students to recognize the limitations of their existing understanding and then, to jointly make sense of the system at the functional and behavioral level.

Since the content of the two versions of hypermedia is identical except for different conceptual organization of hypermedia, our results indicate that different conceptual representations affect how students learn collaboratively. Clearly, we are limited in the conclusions that we can draw based on data from two dyads. We are currently engaged in collecting and analyzing additional data to see if the collaboration patterns that we identified in this study are replicated.

Conceptual representations make a difference in how students engage in collaborative learning. Our in-depth discourse analysis suggests that the conceptual representation embodied in hypermedia affects collaborative knowledge construction. These results have implications for learning and instruction about complex systems. Too often, learning about complex systems means learning vocabulary, usually about structures (AAAS, n.d.). These results suggest that organizing learning around the functions and behaviors of the system engages learners in an effort after meaning. Moreover, our results suggest that different conceptual representations provide different affordances for constructive processing and collaborative conceptual change.

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