Supporting authoring and learning in a collaborative hypertext system: The Annotated Egret Navigator.

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Contents

1 Introduction

This research is concerned with how people collaboratively author and learn. More specifically, it is concerned with how to design and implement a hypertext system to support collaborative authoring and learning. It will provide information on the following questions:

1. What breakdowns occur in collaborative authoring and learning?
   (a) What types of breakdowns are due to moving collaboration on line?
   (b) What types of breakdowns are due to our collaborative methods?
2. How does hypertext support collaborative learning?
   (a) What kinds of hypertext structure are necessary for collaborative learning?
   (b) What additional tools are needed for collaborative learning?
3. How do authors create hypertext documents?
   (a) What kinds of hypertext structure are necessary for collaborative authoring?
   (b) What additional tools are needed for collaborative authoring?
4. What are the reading patterns of hypertext users?
5. What tools help the readers navigate in the hypertext document?

We are investigating these issues through the design, implementation, and evaluation of AEN [1], a hypertext collaborative authoring and learning tool.

These issues are becoming more and more important each day. The use of hypertext as a structuring mechanism for richly interdependent information is becoming more widespread, and finds application in many areas of software engineering and other fields.

The remainder of this paper is structured as follows, Section 2 introduces collaborative learning and authoring in AEN. Section 3 is a discussion of how we are going to answer the issues raised above. Section 4 examines other collaborative learning and authoring systems and how they compare to AEN. Section 5 discusses future directions for AEN.

2 Collaborative Learning and Authoring in AEN

Over the past five months, we have experimented with and redesigned AEN, a reader and authoring system for hypertext, that places equal weight on supporting the following: (1) on-line collaborative learning, (2) collaborative authoring facilities and (3) collecting data about user interaction with the hypertext document. A fourth requirement of the system is rapid response time. This system has undergone extensive evolution as we learned more about the implications of these requirements and their often conflicting natures.

AEN is a collaborative, instrumented learning/authoring tool built upon the Egret hypertext database system [9]. AEN consists of a hypertext document and several tools to support collaboration. The hypertext document represents the text from which the students learn and the product of collaboration among the participants in the class.

[1] Annotated Egret Navigator

The initial requirements of AEN were to create a virtual classroom and move nearly all of the lectures for a class on-line into a hypertext document called *The Annotated Egret*. The class' subject is how to design and construct collaborative systems using Egret. This class would meet both on-line and off-line for discussions about issues. Most of the interaction in the class would occur through annotation of the lecture material with new hypertext links to questions, comments, and insights. A few actual classroom meetings would be supplementary forums to discuss things learned or questioned through on-line activities [8]. The Fall 94 ICS613 class is currently using AEN as the priciple learning environment.

The following three sections provide a detailed look at AEN's data model, tool support and process model for collaborative authoring and learning.

2.1 Structure of Data in AEN

2.1.1 Node Types

AEN has two different classes of nodes: artifact nodes and figure nodes. Artifact nodes represent textual information in the hypertext document. Figure nodes represent graphical information.

Artifact nodes contain HTML code that provides formating directives and inter-node links. There are four subclasses of artifacts:

- **document:** Nodes that contain the text of the document created by the participants.
- **comment:** Nodes containing the reactions of the participants to the contents of other nodes.
- **quicky quiz:** Nodes that contain exercises for the participants to complete.
- **quicky quiz answer:** Nodes that contain the participant's solutions to the quicky quiz nodes.

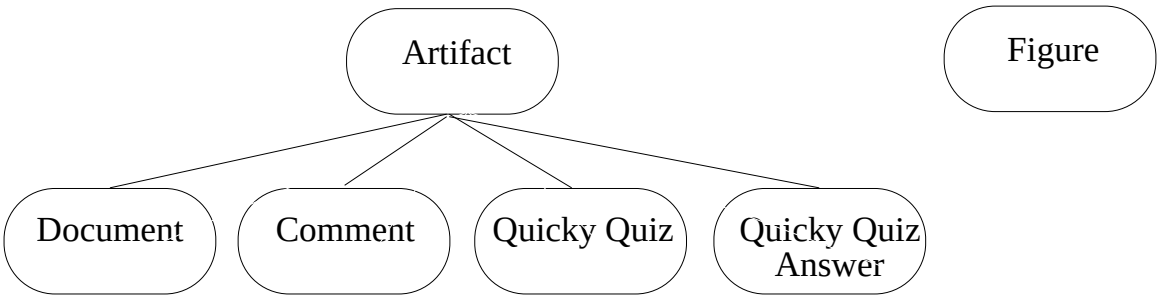

Figure 1: **Data Relationships in AEN**

Figure nodes contain the graphics used by xview to display the figures. Users can link figure nodes into artifact nodes. Since figure nodes contain graphical information rather than HTML code, users cannot annotate them like artifact nodes. Figure 1 shows the relationships between the node types.

Link Type	Source Node	Destination Node	Description
Include	document	document	Backbone structure of hypertext document
Xref	document	document	Cross reference
See_Comment	Any	comment	Points to a Comment
See_Quicky_Quiz	Any	Quicky Quiz	Points to a Quicky Quiz
See_Quicky_Quiz_Answer	Quicky Quiz	Quicky Quiz Answer	Points to a Quicky Quiz Answer
See_Figure	Any	Figure	Points to a Figure

Table 1: Link Types

2.1.2 Link Types

AEN also has 6 types of links: Include, Xref, see_Quicky_Quiz, see_Quicky_Quiz_Answer, see_Comment, and see_Figure. AEN restricts the type of the source and destination nodes for each type of link. Table 2.1.2 describes the different links. These restrictions allow AEN to support a structure known as the AEN Backbone.

2.1.3 The AEN Backbone

The AEN Backbone is the basic structure that defines *The Annotated Egret* document. It begins with a Document node that contains Include links to the different "chapters" in *The Annotated Egret* document. The Backbone is the skeleton on which *The Annotated Egret* is built. It provides a spine for the hypertext.

2.2 Mechanisms for Data Manipulation in AEN

The previous section discussed the Data Model for AEN. This section discusses mechanisms to manipulate artifacts: access control, table of contents, and nodelist. The section concludes with two mechanisms to support real time communication in AEN, Snoopy and Partyline.

2.2.1 Access Control

AEN's access control mechanisms implement three forms of access to individual nodes: read access, write access, and annotation access. Users can set each form of access for individual users or for all users. When a user has read access for a specific node, they can retrieve and view it. Similarly, when a user has annotation access they can comment on the node and make links from the node, but not edit its contents. Finally, when a user has write access to a node, they can change the text in the node.

The read access mechanism is the primary access control mechanism. The owner of a node can restrict all access by denying other users read access. Users cannot annotate, or change the contents of nodes they cannot read.

2.2.2 Table of Contents

The access control mechanism determines which nodes a user may read, but it provides no navigational aids to the user. To help the user navigate through the hypertext document AEN has a dynamically generated table of contents (TOC). The user can ask for a new TOC at any time. AEN calculates the new TOC from a starting node that the user chooses. The TOC generation algorithm only looks at document nodes the user has read access to and include links. It will only visit the children of a node once. This rule breaks any cycles in the traversal of a hypertext network. Once the TOC is displayed the user can decide what level of detail they want to view. Figure 2 shows what an example TOC looks like. The user can create multiple TOCs starting from different document nodes. The table of contents should help users find their way through the hypertext document. The TOC provides orienting information about the hypertext network and prevents the "lost-in-hyperspace" phenomenon. Another mechanism AEN has to help the user navigate in the hypertext document is node lists.

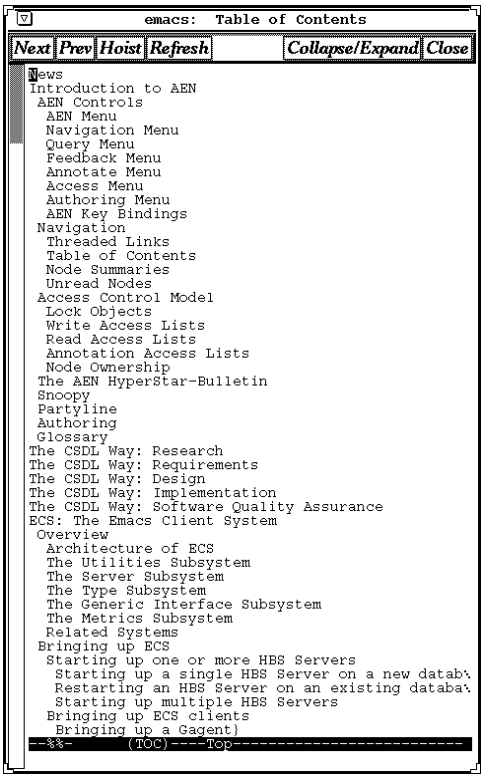

Figure 2: **AEN's Table of Contents**

2.2.3 Node Lists

Node lists are a list of nodes based upon certain criteria. AEN provides the user with several built in criteria for building these lists. First, AEN allows the user to get a list of all the nodes of any type. Second, the user can get a list of all the nodes they have not read yet or that have changed since the last time they were on AEN. Finally, AEN allows the user to

get a list of all the nodes they own. All of the node lists provide the user with a list of nodes from which they may select and view. Figure 3 shows what a node list of unread document nodes would look like.

Figure 3: **Unread Document Node List**

All of the above mechanisms build upon the basic hypertext document, but we believe that a plain hypertext document is not good enough for effective collaboration. To fully support collaboration there should be a "physical" presence in the hypertext document. Users can see who else is reading the document, what section they are in and communicate to any one else using AEN. These features are difficult to support by just using hypertext. The following two mechanisms provide these features in AEN.

2.2.4 Snoopy

The Snoopy mechanism allows the user to see who else is at work and have an idea of what they are working on. It displays basic information about the connection status and last read node of the users of AEN. Figure 4 shows a view of the snoopy buffer.

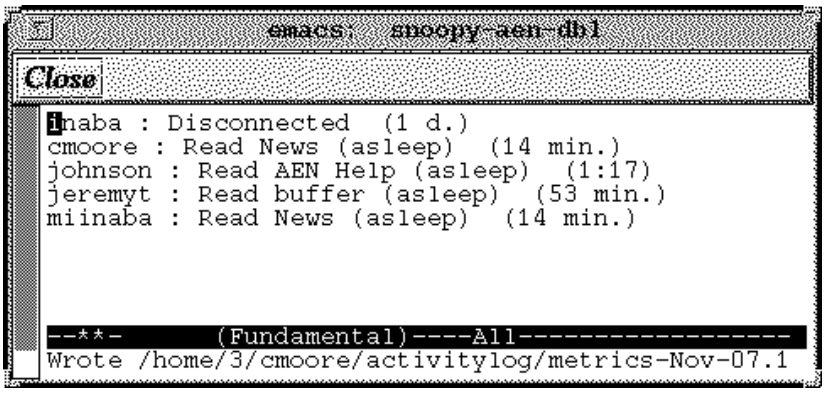

Figure 4: **AEN's Snoopy Buffer**

2.2.5 Partyline

Partyline is a mechanism for passing real time messages to other users of AEN. Partyline allows the user to send a textual message to all the users currently connected to AEN or send a private message to one other user currently connected to Partyline. Figure 5 shows a view of the Partyline buffer.

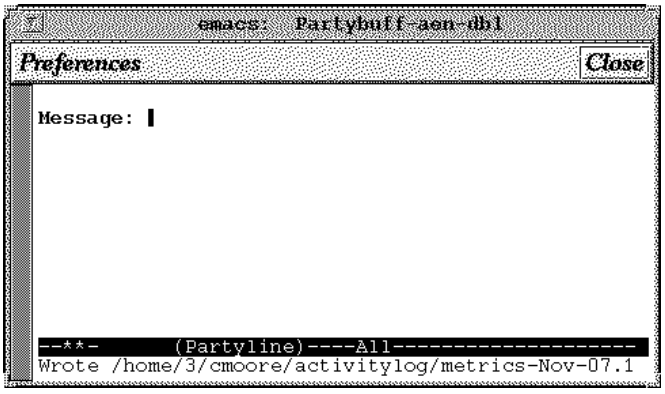

Figure 5: **AEN's Partyline**

Both facilities provide services that are similar to walking into a room containing the other people using AEN. There are some significant differences between AEN's Snoopy/Partyline and the walking into a room. When you walk into a room, you can only see the people in the room. You have no idea how long the people have been in the room and when people left the room. Snoopy gives you this information. You can see how long ago people left the room and how long people have been working on their current task.

In a room many conversations can go on simultaneously and you can listen to any of the conversations in the room. Partyline allows you to "listen" to conversations that are sent to the entire room. In a real room it is easy to have two conversations at the same time since we can tune out other noises. Partyline does not support two "global" conversations well. Since Partyline is text-based, users have to read the messages. When the user receives a message they have to see who sent it. This does not allow them to totally ignore the other conversations in the room. If they actually read the message they focus their attention on the other conversation and may loose their train of thought of their conversation.

One special feature that Partyline does allow is to have private conversations. In a real room you can tell when people are "whispering" to each other. In Partyline there is no indication that two people are "whispering".

Another special feature of Partyline is that it keeps track of conversations. If a user leaves their workstation and don't log out of AEN the Partyline buffer records the Partyline conversations. When they return, the conversations are still accessible in the Partyline buffer. The other users in AEN will know that they still can "hear" the conversations since Snoopy tells them that the user is asleep. Snoopy displays the asleep message if the user has not done anything in a while. Partyline allows a user to be paged. Even though the user might be asleep the persistence of Partyline will tell them they have been paged. They can respond to the page when they return.

2.3 AEN's Process Model

All of the above mechanisms are used by AEN to support collaborative learning and authoring. The next sections discuss how these mechanisms are used for collaborative learning and authoring.

2.3.1 Collaborative Learning

For collaborative learning the hypertext document represents the textbook for the class and the instructor's lectures. When students have questions about the textbook or "lectures", they can ask their questions by annotating the text. The instructor or other students can answer the questions by making annotations on the original question. This way "in-class discussions" can take place about different topics. By using the access control mechanism students or instructors can decide who gets to read the node and who can participate in the discussions. This allows groups to collaborate on a question or project easily. When the group is ready, they can allow the rest of the class to view their answer or project. To find out if anything has changed on their project the students can use the node lists to see what nodes have changed. This way they will waste less time searching for new information.

The Snoopy and Partyline features expand AEN's textbook by providing synchronous communications. Students can get together in AEN and discuss the concepts presented in the text. They can work together on solving the quizzes or projects presented in AEN. Snoopy and Partyline allow the instructor to hold office hours by being "present" in AEN at given times. The students can ask the instructor questions and receive answers immediately. The instructor could have a group discussion with all the students present in AEN. If anyone decides that they want to save the discussion they can create a node in the hypertext document and paste the conversation into it. This way a permanent record of the discussion can be kept.

The combination of hypertext document and synchronous communications allows the students to learn in many ways. They can learn by exploring the text, asking questions, answering questions raised by their fellow students, building their own hypertext sections or by answering the exams and quizzes added by the instructor. As the students learn, the hypertext document will be evolving. The instructor will change the text to answer the questions raised by the students. The students will be creating sub-documents in the hypertext document to explore the subject.

2.3.2 Collaborative Authoring

AEN supports two methods for collaborative authoring: *proofreading & trading the lock*. In the proofreading method the author can create a node and "publish" it by changing the read and annotate access for the document. Then other co-authors can make comments as simple as proofreading comments or as complex as philosophical discussions. These comments could be thought of as marginal notes suggesting changes, new ideas, or just general comments on the subject. The author can read the comments and make changes to the document or comment on the comments. This can lead to discussions on the contents of the document.

In the trading the lock method the author can create a node and allow other authors to edit the node by giving them read and write access to the node. When a node is saved, all

connected users viewing the node see the changes. In this way two or more co-authors could trade the lock and make changes that all the co-authors will see.

3 Evaluation

In order to provide data to address the questions raised in Section 1, the following case study in the usage of AEN is being performed.

3.1 Duration

Starting in the Fall of 1994 12 students in the graduate seminar ICS 613 are using AEN to learn about designing and implementing collaborative systems using Egret. The experiment started in September 1994 and is continuing through December 1994. Which corresponds to the Fall semester. During this period the contents of the hypertext document will be incrementally constructed while the system is in use.

3.2 Method

The method for this experiment is to collect metrics data generated by both authors and readers of the hypertext, collect bug reports and suggestions, and conduct a user survey. The data will be analyzed both during and at the end of the experiment. The metrics will be collected on:

- node creation
- reading the contents of a node
- changing the contents of a node
- locking of nodes
- changing the access privileges for a node
- using different tools (ie Table of Contents, Node list, Unread Nodes)

A questionnaire will be developed to gain information about the users of the systems and their evaluation of the system. More specifically:

- How much hypertext experience the users had before the class
- Which tools were the most helpful
- How much each student learned from the class
- Which features were the most convenient to use

AEN has a Feedback menu that allows the users to send suggestions and bug reports. These suggestions and bug reports will be analyzed to help answer the research questions. The ICS 613 class has periodic meetings. Suggestions or comments raised in these meetings will also be used to help answer the research questions. These suggestions and bug reports will be classified in the following manner.

- Are they inside or outside our paradigm.
- Do they involve a major or minor redesign of the system to implement.
- Are they important or nonessential.

3.3 Data Analysis

The data collected will consist of metrics data, user suggestions, bug reports and user questionnaires. Let's revisit the central questions of this research objective, and discuss how this data can be used to assess them.

1. *What breakdowns occur in collaborative authoring and learning?*

   By looking at the questionnaires we can see how the users feel about AEN as a collaborative learning and authoring tool. The user's input will help us understand which tools provided by AEN they disliked. The bug reports and suggestions will also tell us what problems they had using AEN. We can also look at the answers to the exercises and projects to guage the knowledge learned by the users. By looking at the metrics we will see what patterns the users used and what patterns lead to difficulties.

   (a) *What types of breakdowns are due to moving collaboration on line?*
   The comments raised in class will help us find out if face to face meetings are required for collaboration. The questionnaire will also ask about how much time was spent in face to face meetings outside the context of the class. By looking at the bug reports and the suggestions we can get an idea what the users liked and what the users did not like about AEN. This should give us an idea of what problems the users had in collaborating on line.

   (b) *What types of breakdowns are due to our collaborative methods?*
   The user questionnaires and suggestions made by the users will help us determine if our methods are correct for this group of students. The suggestions will tell us what features the users want to have. The questionnaires will tell us which features of AEN were not helpful or were misleading.

2. *How does hypertext support collaborative learning?*

   The metrics will help us find out what types of nodes are used. The metrics will also tell us how the users answered "collaborative" assignments. We can tell how a group answered the question. Some of the possible ways they could collaboratively solve problems are:

   - Alternatively Edit: They could create a solution and then take turns editing the solution.
   - Proof Read: They could create a solution and then proof read the solution
   - Discuss and Solve: They could create a discussion tree about the solution then create the solution based upon the discussion
   - Combination of the above methods

(a) *What kinds of hypertext structure are necessary for collaborative learning?*
By looking at the metrics and the types of nodes created we can see how the users collaborated. Did they create discussions through comments or did they create separate collaborative documents?

(b) *What additional tools are needed for collaborative learning?*
The questionnaire and suggestions will give us an idea of how much the other tools like Partyline and Snoopy were used to aid collaboration. The user's suggestions will give us a good idea of what tools are missing or are not necessary in AEN. The classifications of the suggestions should help us determine how good AEN's paradigm is.

3. *How do authors create hypertext documents?*

The metrics data will tells us how the users created new nodes and when they changed the access privileges to allow the other users to read the nodes. We should be able to determine general strategies for authoring hypertext document. Some possible strategies are:

- Build content then structure: The author creates the contents of the nodes in a single node then creates the separate nodes in the network and cuts and pastes the data into them.
- Build structure then fill content: The author could "outline" the document by creating the structure of the nodes and then fill in their contents.
- Iterative: The author could start filling the contents of a node then build another node when the contents dictate a new node and then start filling the contents of the new node.

The user's suggestions will also give us insight into what tools they want to aid in the authoring process.

(a) *What kinds of hypertext structure are necessary for collaborative authoring?* The metrics will tell us how authors collaboratively created a document. Did they take turns editing the document or did they use the proof reading method?

(b) *What additional tools are needed for collaborative authoring?*
The metrics data will tell us which tools were used the most. The user questionnaires will tell us which tools the author's liked the most. The user's suggestions will show us what addtional tools to include in AEN's design. The metrics and questionnaires should correlate well. If they do then we can conclude that those tools are helpful in authoring a hypertext document.

4. *What are the reading patterns of hypertext users?*

The metrics data will tell us exactly in what order the users read the individual nodes in the hypertext document. We will generate a "map" of activity for each user. We hope to determine general patterns for the users. Some general patterns might be,

- Linear: The user generally reads through the document once from one node to the next.

- Hunt and peck: The user jumps from one node to another that is not connected by a link.
- Combination: The user might hunt and peck until a particular area of the hypertext network is found then read linearly.

5. *What tools help the readers navigate in the hypertext document?*

   The metrics data will tell us which tools were used the most. The user questionnaires will tell us which tools the user's liked the most. The user's suggestions will tell us what new tools to include in AEN's design. The metrics and questionnaire should correlate well. If they do then we can conclude that those tools are helpful in navigating in a hypertext document.

4 Related Work

AEN's set of features were designed to explore the issues presented in the introduction. AEN provides a typed hypertext document, dynamic user defined table of contents, real-time communications with other users of the system, real-time knowledge of what the other users of the system are doing and access control for each node. Other hypertext or collaborative editors provide different combinations of these features. The final thesis will look closely at the following collaborative or hypertext systems abilities to explore the issues raised in Section 1.:

- SEPIA [6]: a collaborative hypermedia authoring environment.
- ShrEdit [15]: a collaborative editor.
- HyperCard: a Hypertext system that does not support collaboration.
- WWW [2]: a global Hypertext system.
- Intermedia: one of the largest and oldest hypermedia systems designed to support learning.
- GROVE [4]:
- Quilt [5]:
- NodeCards [7, 14, 10]:
- ENFI [3]:
- PREP [12, 11]:
- SASE [1]:
- WE [13]:

5 Future Directions

An area that this research does not look at is the difference between collaboration in the small and collaboration in the large. Also the difference between a static hypertext reader like Mosaic and AEN is not investigated. AEN dynamically generates many navigation aids that Mosaic cannot at this time. What is the effect of these navigation aids on the reader and author of hypertext?

A User Questionnaire

The following questionnaire will be given to each of the users of AEN during the experiment. The questionnaires will be anonymous.

Please circle the answer or number which most appropriately reflect your impressions. Not Applicable = NA. There is room on the last page for your written comments.

Previous Experience:

Emacs:	_ < 3 months	Hypertext: _ < 3 months
	_ 3 - < 6 months	_ 3 - < 6 months
	_ 6 - < 1 year	_ 6 - < 1 year
	_ 1 year - < 2 years	_ 1 year - < 2 years
	_ 1 year - < 2 years	_ 1 year - < 2 years
	NA	NA

Collaborative Systems:
_ < 3 months
_ 3 - < 6 months
_ 6 - < 1 year
_ 1 year - < 2 years
_ 1 year - < 2 years
NA

Overall reactions to AEN:	terrible	1	2	3	4	5	6	7	8	9	wonderful	NA
	frustrating	1	2	3	4	5	6	7	8	9	satisfying	NA
	dull	1	2	3	4	5	6	7	8	9	stimulating	NA
	difficult	1	2	3	4	5	6	7	8	9	easy	NA
	rigid	1	2	3	4	5	6	7	8	9	flexible	NA
Learning to operate AEN:	difficult	1	2	3	4	5	6	7	8	9	easy	NA
Getting Started	difficult	1	2	3	4	5	6	7	8	9	easy	NA
Learning advanced features	difficult	1	2	3	4	5	6	7	8	9	easy	NA
Time to learn to use AEN	slow	1	2	3	4	5	6	7	8	9	fast	NA
Exploration of features by trial and error:	discouraging	1	2	3	4	5	6	7	8	9	encouraging	NA
Exploration of features	risky	1	2	3	4	5	6	7	8	9	safe	NA
Discovering new features	difficult	1	2	3	4	5	6	7	8	9	easy	NA
Remembering names and use of commands:	difficult	1	2	3	4	5	6	7	8	9	easy	NA
Can tasks be performed in a straight-forward manner?	never	1	2	3	4	5	6	7	8	9	always	NA
Are the needs of both experienced and inexperienced users taken into consideration?	never	1	2	3	4	5	6	7	8	9	always	NA

Please rank the following tools:

I used the Table of Contents	never	1	2	3	4	5	6	7	8	9	always	NA
I used Unread Nodes	never	1	2	3	4	5	6	7	8	9	always	NA
I used Nodes by type	never	1	2	3	4	5	6	7	8	9	always	NA
I used Owned Nodes	never	1	2	3	4	5	6	7	8	9	always	NA
I used the Back & Navigation Menu	never	1	2	3	4	5	6	7	8	9	always	NA
I used History List	never	1	2	3	4	5	6	7	8	9	always	NA
I used Snoopy	never	1	2	3	4	5	6	7	8	9	always	NA
I used Partyline	never	1	2	3	4	5	6	7	8	9	always	NA

The Table of Contents is helpful	not at all	1	2	3	4	5	6	7	8	9	very helpful	NA
Unread Nodes is helpful	not at all	1	2	3	4	5	6	7	8	9	very helpful	NA
Nodes by type is helpful	not at all	1	2	3	4	5	6	7	8	9	very helpful	NA
Owned Nodes is helpful	not at all	1	2	3	4	5	6	7	8	9	very helpful	NA
The Back & Navigation Menu is helpful	not at all	1	2	3	4	5	6	7	8	9	very helpful	NA
History List is helpful	not at all	1	2	3	4	5	6	7	8	9	very helpful	NA
Snoopy is helpful	not at all	1	2	3	4	5	6	7	8	9	very helpful	NA
Partyline is helpful	not at all	1	2	3	4	5	6	7	8	9	very helpful	NA

Please add any additional comments here:

References

[1] Ronald M Baecker, Dimitrios Nastos, Ilona R. Posner, and Kelly L. Mawby. The user-centered interative design of collaborative writing software. In *ACM INTERCHI'93 Conference on Human Factors on Computing Systems*, pages 399–405, 1993.

[2] Tim Bemers-Lee, Robert Cailliau, Ari Luotonen, Hennik Nielson, and Arthur Secrit. The World Wide Web. *Communications of the ACM*, 37(8), August 1994.

[3] Bertram Bruce, Joy K. Peyton, and Tren Batson editors. *Network-based classrooms: promises and realities*. Cambridge University Press, 1993.

[4] C. Ellis, S.J. Gibbs, and G. Rein. Design and Use of a Group Editor. Technical Report STP-263-88, MCC Software Technology Program, 1988.

[5] R. Fish, R. Kraut, M. Leland, and M. Cohen. Quilt: A Collaborative Tool for Cooperative Writing. *Proceedings of ACM SIGOIS Conference*, 1988.

[6] Jorg M. Haake and Brian Wilson. Supporting Collaborative Writing of Hyperdocuments in SEPIA. *Sharing Perspectives, CSCW92*, 1992.

[7] Frank G. Halasz. Reflections on notecards: Seven issues for the next generatoin of hypermedia systems. In *ACM Hypertext'87*, pages 345–4365, 1987.

[8] Philip M. Johnson. Annotated Egret Navigator: Initial Requirements and Design Issues. Technical Report ICS/CSDL 94-06, Collaborative Software Development Laboratory, Department of Information and Computer Sciences, University of Hawaii, Honolulu, Hawaii 96822, 1994.

[9] Philip M. Johnson. Experiences with EGRET: An Exploratory Group Work Environment. *Collaborative Computing*, 1(1), 1994.

[10] Catherine C. Marshall and Peggy M. Irish. Guided tours and on-line presentations: How authors make existing hypertext intelligible for readers. In *ACM Hypertext'89*, pages 15–26, 1989.

[11] Christine M. Neuwirth, Ravinder Chandhok, David S. Kaufer, Paul Erion, James Morris, and Dale Miller. Flexible diff-ing in a collaborative writing system. In *ACM CSCW'92 Conference on Computer Supported Cooperative Work*, pages 201–250, 1992.

[12] Christine M. Neuwirth, David S. Kaufer, Ravinder Chandhok, and James Morris. Issues in the design of computer support for co-authoring and commenting. In *ACM CSCW'90 Conference on Computer Supported Cooperative Work*, 1990.

[13] John B. Smith, Stephen F. Weiss, and Gordon J. Ferguson. A hypertext writing environments and its congnitive basis. In *ACM Hypertext'87*, pages 195–214, 1987.

[14] Randall H. Trigg. Guided tours and tabletops: Tools for communicating in hypertext environment. In *1988 Conference on Computer Supported Work*, pages 216–226, 1988.

[15] unknown. Shredit 1.0: A Shared Editor for the Apple Macintosh, User's Guide and Technical Description. Technical report, Cognitive Science and Machine Intelligence Lab, University of Michigan, Ann Arbor, 1990.