Design of a Sensemaking Assistant to Support Learning

Dagobert Soergel[1], Pengyi Zhang[2]

University at Buffalo, United States[1]
Department of Information Management, Peking University, China[2]

Abstract

Thinking tools that assist by externalizing thought processes and conceptual structures so they can be manipulated potentially improve user learning. We propose the design of a sensemaking assistant that integrates many such tools. Our design emerged from an intensive study of sensemaking by users working on real tasks, providing a link from users to developers. Sensemaking is the process of forming meaningful representations and working with them to gain understanding, possibly communicated in a report, to support planning, decision-making, problem-solving, and informed action. At the heart of our design is a set of tightly integrated tools for representing and manipulating a conceptual space: tools for producing and maintaining concept maps, causal maps/influence diagrams, argument maps, with support through self-organizing semantic maps, importing concepts and relationships from external Knowledge Organization Systems, and inferring connections between texts; further a tool for organizing information items (documents, text passages notes, images) linked to the concept map. The sensemaking assistant we envision guides users through the sensemaking process; for each function it suggests appropriate cognitive processes and provides tools that automate tasks. The comprehensive sensemaking model introduced in specifies functions in the iterative process of sensemaking: Task analysis and planning; Gap identification (tools for both: brainstorming, finding documents on the task); information acquisition, data seeking and structure seeking (search tool: finding databases, query expansion, passage retrieval; summarization tool); information organization, building structure, instantiating structure, information synthesis / new ideas / emerging sense (conceptual space tools mentioned above); information presentation, creating reports (from concept map to outline, guide through the writing process [5], analyze draft writing for coherence and clarity). The system tracks sources. Users using a sensemaking assistant may well internalize good ways for intellectual processes and good conceptual organization in addition to learning a useful application. The paper will provide some evidence from the literature and propose further testing.

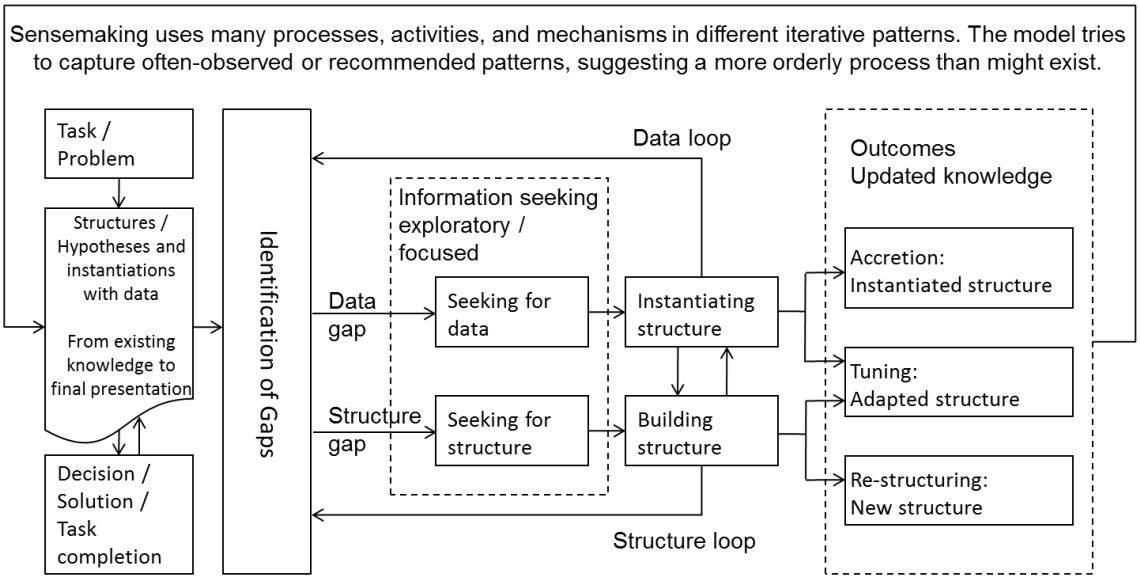
Keywords: *Sensemaking assistant, thinking tools, computer support for learning*

1. Introduction

We present the design of a sensemaking assistant that can be used by users in the classroom or for work on assignments, to improve meaningful learning, Our design is based on a detailed observational study of users' sensemaking while they worked on real tasks, providing a link from users to developers[1]. We are not concerned with rote learning but with meaningful learning from a constructivist point of view ─ the user constructs the knowledge or understanding to be learned.

"Sensemaking can be defined as creating an understanding of a concept, knowledge area, situation, problem, to find a problem solution, to inform decisions and actions, or to support learning ─ integrating the newly found understanding into memory. An important part of sensemaking involves making clear the interrelated concepts and their relationships in a problem or task space." ([2], first sentence modified).

Figure 1 shows our model of sensemaking which defines component processes but stresses that there are many ways in which these components can be arranged and that the process is highly iterative.

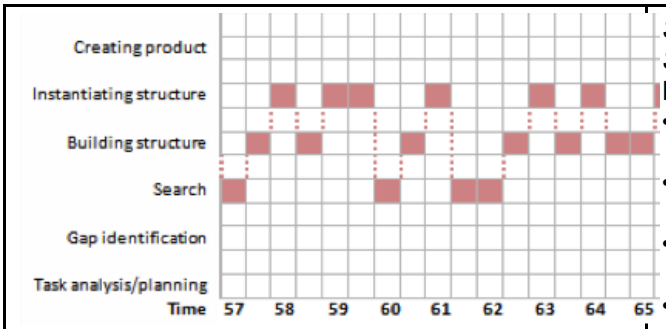


Information seeking is often divided into *searching for data and structure* and *searching for / extracting data and pieces of structure.*

Most sensemaking processes involve both external and internal representations, and the interplay between them. In each process, the cognitive mechanisms listed below can be used as applicable.

Inductive (data-driven, bottom-up)	**Structure-driven (logic-driven, top-down)**	**Both or Neither**
Key item extraction	Definition	Comparison
Restatement	Specification	Analogy
Judgment or evaluation	Explanation-based mechanisms	Classification
Summarization	Elimination	*Stereotyping*
Schema induction	Inference	Semantic fit
Generalization		Questioning
		Socratic dialogues

Figure 1. A Cognitive Process Model of Information Seeking and Sensemaking ([2] pp. 19)



Search – Building Structure – Instantiating Structure.
In this example, the sensemaker

- looked through her copied notes on polling results (search),
- added a concept “Nuclear Energy” in her concept map (building structure), and
- typed in “Mixed Reaction 47 for 41 against” (instantiating structure),
- then added another concept “Offshore drilling”, and typed in “Repubs and Independents” (more building and instantiating structure)
- then searched again, found another concept, ...

Figure 2. Example of a Process Sequence [3]

Sensemaking and meaningful learning involve representation and manipulation of the conceptual space, relating the user's internal conceptual space to external representations that provide new concepts and new data and creating and manipulating new external representations that can then be internalized. Our system is designed to assist the user in navigating texts, visualizations, concept maps, etc., extract concepts and relationships, build a meaningful structure, and use that structure to organize empirical data. Many cognitive processes (shown in Figure 1) are available for users to use in this task [2, 3, 4]. Using these processes is a skill to be learned. They will be included in the tool box with explanations and examples available

2. System Architecture

Our proposed sensemaking assistant consists of three components:

1. an **interlinked multi-compartment data store**,
2. a **workflow organizer** that guides the users through the overall sensemaking process
3. a **toolbox** that provides many useful tools. We envision an open architecture such that many existing tools can be incorporated. Some tools are processes and techniques for the user to learn and carry out (such as advanced techniques in Google or cognitive processes in sensemaking), others offer mechanical assistance (such as highlighting text and creating a note with one click), and still others carry out complex automatic processes to deliver useful results (such a extracting concept relationships or definitions from text).

2.1 Data store

Comprehensive sensemaking uses and produces many types of information objects, for example, queries, search results, full-text documents, notes (consisting of text and tags) that may have quotes or summaries from papers or users' own insights, concept maps (which, in turn, consist of nodes and typed links (arcs), entity-relationship statements, final report, events in the action history, the user profile. All these information objects are stored in the database, Many tools, such as notes software or concept mapping software, have their own store, which must be linked by the system.

2.2 Sensemaking workflow organizer

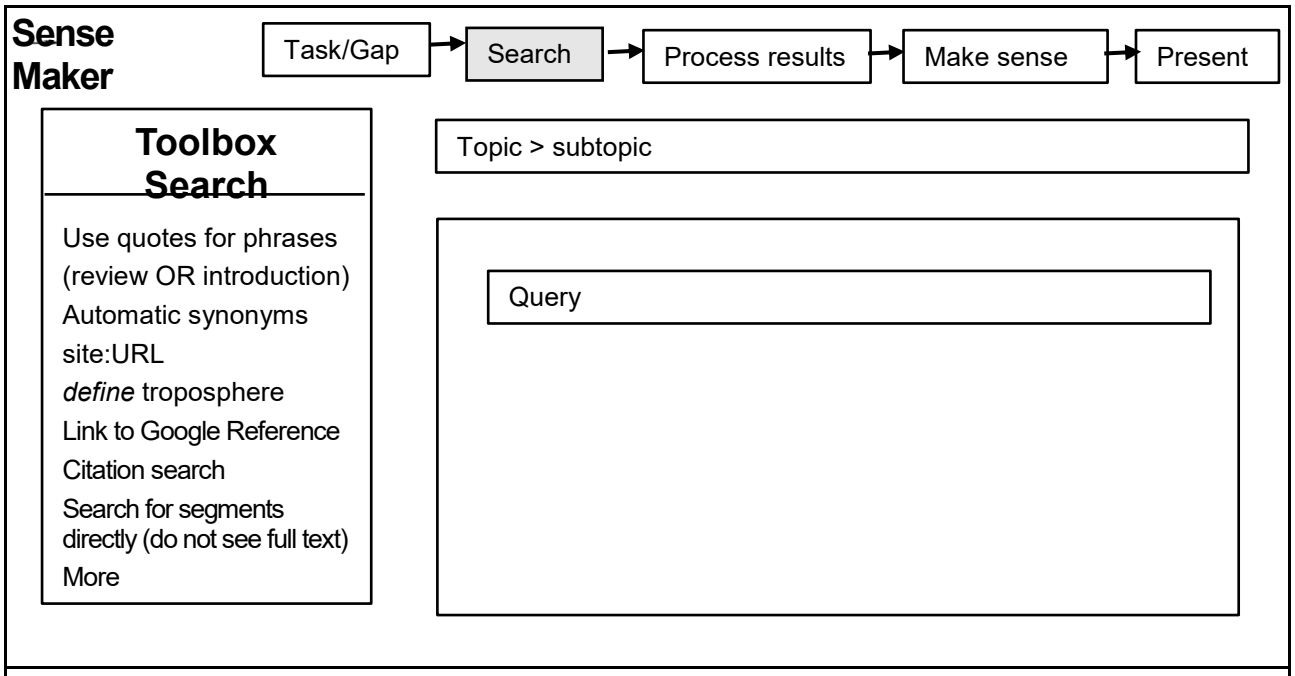


Figure 3. Workflow Organizer. Main Screen

First the user is presented with the main screen shown above. Task/Gap is highlighted first. When the user clicks it, she will get to the screen for entering the description of the task, consisting of a title and ideally a few lines of text, and a description of the information gap. If there is enough text, the system will use linguistic analysis to create a draft concept map the user can edit [5]. Or a user can draw a concept map instead of entering text. There would also be a checklist of types of tasks that needs to be developed. Some examples:

- Learn about / write a paper or report about a plant or animal, a geographical feature, an historical or contemporary situation or event, a disease, or a surgical procedure
- Define a topic for a research study, including theoretical framework, variables, significance

Upon completing the task description, the user in returned to the main screen with **search** highlighted and the most important search tools listed in the tool box on the left (as shown in Figure 3). The system may have pre-filled the query for the user to edit. The user can refine the query using Google (default search engine) syntax options, or she can click *automatic synonyms* for query term expansion. With a highly advanced search engine that can represent document content as a document concept map, a query concept map can be used for more precise search. The system will

also use the user profile to filter results, for example by appropriateness to the user's reading level and subject knowledge. The user can also bypass search and paste results into the result box.

Result processing and making sense overlap. Just to mention two tools:

- To judge the relevance of a document or segments, consider its contribution to the task/topic: *directly relevant, comparison to similar topic, providing context*.
- Extract relevant segments, manually with the assistance of note taker software or automated.

Presenting / authoring can be supported in many ways. There is even software that helps young children tell a story in pictures

There will be much back and forth in going through these steps. While making sense or even while preparing the presentation a new information need may surface and a new search is needed. Search may be external or just internal to the system. During authoring a need for further clarification in sensemaking may surface.

2.3 Tool box

At the heart of our design we envision a set of tightly integrated tools for representing and manipulating a conceptual space. The comprehensive sensemaking model (Figure 1) specifies functions in the iterative process of sensemaking: Task analysis and planning; Gap identification (tools for both: brainstorming, finding documents on the task); information acquisition, data seeking and structure seeking (search tool: query expansion, passage retrieval; summarization tool); information organization, building structure, instantiating structure, information synthesis / new ideas / emerging sense (conceptual space tools mentioned above); information presentation, creating reports (from concept map to outline, guide through the writing process)There are no limits to imagining useful tools. Table 1, while it is big, gives just a smattering of examples. For many of the tools one or more implementations exist (a few are referenced), others are admittedly more "pie in the sky".

.**Table 1. Example tools sorted by function**

Tools for many steps	Use Knowledge Organization Systems (KOS) • to show concept connections to the user, • to help with search terms • show concepts in KOS context Adapt methods shown, relevance relationships, other elements to subject area Keep source with everything Support for idea generation from bits and pieces of information collected Search for analogies Concept maps, causal maps/influence diagrams, argument maps, support through self-organizing semantic maps, importing concepts and relationships from external Knowledge Organization Systems, and inferring connections between texts [6], [7] Templates, frames (for evaluating documents, for writing a document of a given type)
Search tools	Use quotes for phrases In Google (and other search engines) use Boolean OR (review OR introduction) Automatic use of synonyms (query term expansion) Automatic use of hierarchy (hierarchic query term expansion) site:URL Use Google "define", for example define troposphere Google Reference [8], [9] Use citation search. Where available, use reason for citation both forward and backward1 Query formulation by relevance type Find document segments that are relevant Find things that might spark a new connection

Result processing tools	Organize relevance judgments using relevance relationships Extract relevant segments, manually with the assistance of note taker software or automated. Multi-document summaries Reading support: Provide definitions on mouse over Support understanding of documents through helping user extract, then organize segments [10] Identify topics in search results - clustering, often used terms Note taker. Copy selected text to notes with source
Sensemaking tools	Note organizing tool with the ability to link nodes in a concept map to notes [11] Make connections based on same entity or concept mentioned. Knowledge representation for sensemaking, concept maps etc. Populate concept maps from Knowledge Organization Systems Populate concept maps from information extraction Simulation Animation Visualization. graphical representation Cognitive processes for sense making
Authoring tools Presentation tools	Word processor with outlining capability General assistance with writing [12] From concept map create a paper outline (may be automated), considering Automatically place notes into a document outline Analyze writing for Analyze draft writing for coherence Analyze a slide presentation or website for clarity, readability (font size, contrast), and other aspects of usability

3. Conclusions

We presented an ambitious design for a sensemaking assistant that could be implemented incrementally, incorporating many existing tools for specific functions. Sensemaking tools for use in professional practice exist (for examples, see [14]), but our design improves on them. We envision that our system could adapt to a wide range of users, from elementary students to professionals. We are not aware not aware of such systems being used in K-12 or higher education, but we claim (as of yet without proof) that students using a sensemaking assistant may well internalize good ways for intellectual processes and good conceptual organization in addition to learning to use sensemaking tools in general. The system can also be used in teaching/training mode since it does include tools for presentation. While for learning constructing one's own concept maps is best, some information can be absorbed better when presented as one or more concept maps than as text.

Our design aims at combing intelligent information processing with the power of the human mind to achieve optimal understanding and problem solving.

References

[1] Zhang, P. (2010). Sensemaking: conceptual changes, cognitive mechanisms, and structural representations. PhD Dissertation. University of Maryland.

[2] Zhang, P., Soergel, D. (2014). Towards a comprehensive model of the cognitive process and mechanisms of individual sensemaking. JASIST, 65(9), 1733-1756.

[3] Zhang, P., Soergel, D. (2016). Process patterns and conceptual changes in knowledge representations during information seeking and sensemaking. J. Information Science, 42(1), 59-78.

[4] Zhang, P., Soergel, D. (2020). Cognitive Mechanisms in Sensemaking. JASIST, 71 (2): 158-171.

[5] Belkin, N.J., Oddy, R.N. and Brooks, H.M. (1982), "Ask For Information Retrieval: Part I. Background and Theory", Journal of Documentation, Vol. 38 No. 2, pp. 61-71.

[6] CMap software for constructing concept maps. https://cmap.ihmc.us/

[7] Anderson-Inman, L.; Arvindam, A.; Oronzio, M. (2015) The Science Behind Ideaphora. Lake Oswego, OR, 13 p.[Good paper, but the system is inactive]

https://cdn-educators.brainpop.com/wp content/uploads/2015/12/The_Science_Behind_Ideaphora_White_Paper.pdf
[8] Google advanced search URLs https://www.google.com/advanced_search, https://libguides.mjc.edu/c.php?g=255744&p=1706104
[9] Dan Russel's home page, lots of good search advice https://sites.google.com/site/dmrussell/Home
[10] Subramonyam, H. (2019). Designing Interactive Intelligent Systems for Human Learning, Creativity, and Sensemaking. UIST 2019 Adjunct Publication p. 158-161.
[11] PC Magazine Review of Evernote (Windows), Microsoft OneNote, and Bear (Mac) Updated May 28, 2019 https://www.pcmag.com/picks/the-best-note-taking-apps
[12] The Easy Essay - . www.theeasyessay.com.
[13] Hemingway Editor highlights writing that could be more succinct and clear. http://hemingwayapp.com
[14] Nautilus Institute. https://nautilus.org/gps/tools/sense-making-and-mind-mapping-tools/