# LEO: A Learning Environment Organizer to Support Computer-Mediated Instruction[1]

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## Abstract

This paper contains a description of a network-based, Learning Environment Organizer entitled LEO, which takes its impetus from the Assimilation Theory of meaningful learning [1]. LEO represents a new approach to computer-mediated augmentation of face-to-face, or hybrid courses, and a different approach to distance learning course delivery. LEO provides the learner with a graphical advance organizer for the course, links to instructional content, various completion criteria for topics, and a visual representation of student progress. The organizer is non-linear in the sense that it maps only those prerequisites that are necessary for any given topic, creating many potential paths through the material. LEO is part of a software suite entitled "CmapTools" that provides a unique method of knowledge modeling or instructional content structuring. LEO can be used to organize CmapTools-type knowledge models or any other online instructional content. This work presents a description of the software's rationale, basic functionality, look and feel, and a discussion of an example course organizer.

*Keywords:* Assimilation theory, advance organizers, meaningful learning, concept maps, Learning Environment Organizer.

## Introduction

Increasingly, graduates of our educational systems must be able to perform complex cognitive work, and must be able to understand and generalize on basic structural knowledge of a domain. A central tenet of Assimilation Theory [1] is that meaningful learning is more flexible, generalizable, and

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long-lasting than rote learning. It is critical that the educational experience promote meaningful learning that fosters integrative thinking based upon integrated, structural knowledge, rather than rote learning of fragmentary, decontextualized facts. The work in this paper describes a new approach to the presentation of computer-mediated courses and a tool to support the approach entitled LEO, a Learning environment Organizer [2, 3]. LEO is based upon Assimilation Theory generally, and the idea of an advance organizer specifically. Ausubel et al. state that advance organizers present the student an overview of more detailed material *before* they actually confront it, and provide organizing elements for the particular content to be learned.

A course representation created with LEO presents the structure of the course itself as an advance organizer. The goal of LEO is to offer support for the learning endeavor in a fashion that fosters the development of well-integrated, structural knowledge. An organizer created with LEO is based upon a concept map-like graphical representation of topics, their sequences, and additional explanatory information regarding the way the topics interrelate. It presents essential dependency relationships among topics in a course, points the student to instructional content pertinent to the topic, and provides access to the content at the student's request. A fundamental goal of presenting a course in this fashion is to afford the student greater choice in the selection and sequence of topics than that afforded by a typical, linearized course. A second major goal is to encourage active knowledge construction and assimilation by presenting a freely browsable interface to course content. LEO achieves significant added capability from its integration into "CmapTools" [4], a knowledge modeling environment [5, 6, 7] with a client-server architecture [8].

This work contains a description of LEO and its context, starting with the benefits of using an advance organizer to foster acquisition of integrated structural knowledge. CmapTools, the knowledge modeling software of which LEO is a part, will be described. A discussion of the basic features and the look and feel of a knowledge model of the sort created with CmapTools will be followed by a description of the tool itself and how an organizer works with a knowledge model to create a new style of learning environment. An elaboration of how LEO can be used in the more general case to organize any course comprised of hypermedia content will follow. The paper will conclude with a description of an example organizer for a Computer Science course entitled Data Structures and Algorithms.

## Developing Integrated, Structural Knowledge

Performing decision-oriented, cognitively complex work requires people to be able to analyze large quantities of data, to interpret that data, and to make sound decisions based upon those interpretations. Other sorts of cognitively complex work such as that in technical disciplines require workers to generalize from fundamental principles to problem solutions. Clearly, educational strategies must emphasize meaningful learning and integrative thinking in order to foster development of the sorts of cognitive skills required to perform such tasks.

In order for a learning environment to foster such integrative thinking, it should actively engage the learner in the educational pursuit, afford the learner some measure of control over the educational process, and emphasize attainment of integrated structural knowledge rather than acquisition of perishable factual knowledge. The following sections present a discussion of Assimilation theory and advance organizers including concept maps, and their role in fostering meaningful learning.

### *Assimilation Theory, Advance Organizers and Learning Structural Knowledge*

Assimilation theory [1] addresses the issue of how to promote meaningful concept learning. Ausubel describes two orthogonal dimensions of learning: meaningful versus rote and reception versus discovery. Assimilation theory seeks to describe how rote learning occurs and the pitfalls of learning material by rote. The theory also explains how concepts might be acquired and organized within a learner's cognitive structure in a meaningful fashion through a broad range of teaching/learning strategies on the receptive - discovery dimension.

Ausubel advocates the use of advance organizers to foster meaningful learning, and he describes the role of advance organizers in the progressive differentiation of learned concepts. Ausubel states that subsumptive learning, the learning of details that are related to more general concepts, is more effective than superordinate learning in which the student learns a large number of details and then tries to fit them all together. The advance organizer supports the notion of subsumptive learning by making explicit the general, superordinate concepts to be learned, and how they interrelate. It is into this framework that the learner can progressively articulate details of the concept. Advance organizers foster meaningful learning by both: prompting the learner regarding pre-existing superordinate concepts that are already in the student's cognitive structure, and providing a context of the most general concepts into which the student can incorporate progressively differentiated details.

Ausubel further states that by presenting a global representation of the knowledge to be learned, advance organizers foster "integrative reconciliation" of the subdomains of knowledge, and the ability to understand in a meaningful way, the interconnections among the subdomains. Integrative reconciliation occurs because organizers make explicit either the ways in which previously learned concepts are related, or the fact that they are not related. Such explicit arrangements provide an "economy of learning" [1, p. 194] by avoiding the separation and compartmentalization of related concepts, by making explicit the relationships among similar concepts, and by avoiding potential misconceptions based on the vagaries of how two similar ideas may be related.

Assimilation theory holds that a representation such as an advance organizer, that fosters progressive differentiations of subsumable concepts and the integration of superordinate concepts, can play a salutary role in the meaningful learning of a domain of knowledge. LEO is based upon a graphical representation of concepts and their interrelationships that explicitly presents a global conceptual organization of a knowledge domain to the learner. The various forms that an advance organizer may take and results pertaining to their efficacy are described in the next section.

### *Types of Advance Organizers*

The advent of the Internet and hypermedia/multimedia, have given rise to a broad range of possible representations that may be utilized as advance organizers. Modern advance organizers take the form of text passages [9, 10], graphical representations and maps [11], and description + pictures [12]. When applied to hypermedia, advance organizers might present global concepts, indicate paths through the content, or foster access to individual components. Krawchuk [13] presents a taxonomy of advance organizers that includes traditional textual summaries and basic themes that are presented before instruction, graphical organizers that provide organizations rendered in lines and arrows (like flowcharts), and pictorial graphic organizers. The latter category includes concept maps, that present non-linear representations of information and knowledge to be learned. Advance organizers have been used successfully in a wide range of courses from elementary school [10] to graduate research methodology courses [14]. They have also been used in a wide variety of knowledge domains such as biology [15], foreign language [16], and economics [17].

A substantial body of literature suggests that knowledge maps, concept maps with a constrained set of linking phrases, have utility in helping students learn structural knowledge [18; 19; 20]. Results include findings that learners could recall and interrelate general concepts better after studying maps versus text passages, and that low prior knowledge learners who did not already have well defined structural knowledge of a domain especially gained from the use of maps as study aids. It is a common occurrence in teaching technical disciplines that students attain a substantial amount of detailed knowledge of a course without ever really appreciating the global connections among the various ideas in the course. The attainment of flexible cognitive skills presupposes the attainment of generalizeable, integrated, structural knowledge of the domain of discourse. The use of concept maps can help to students attain such knowledge.

The concept map [21, 22] can be utilized as an advance organizer [23]. Concept maps are comprised of concepts, which are "perceived regularities in events or objects, or records of events or objects designated by a label" [22]. Concept maps structure a set of concepts into a semi-hierarchical framework. More general, inclusive, superordinate concepts are found at the highest levels, with progressively more specific, less inclusive, subordinate concepts arranged below them. In this way, concept maps display Ausubel's notion of subsumption, that new information is often related to and subsumable under more inclusive concepts. All concepts at any given level in a well-formed hierarchy have a similar degree of generality.

The concepts in concept maps are linked together by linking phrases that elaborate their relationships and form propositions. Propositions form semantic units by linking together two or more concepts. Novak states that propositions are the principle units that form meaning. In educational settings, concept mapping techniques have aided people of every age to examine many different fields of knowledge. Much of the assimilation theoretic research to date has involved and exploited concept mapping. Concept maps may be created by the learners themselves to demonstrate what they know about a course of study, or by experts in a knowledge domain in order to convey structural knowledge of the domain to the learner.

## CmapTools

CmapTools [4] is a software suite that is in ongoing development at the Institute for Human and Machine Cognition (IHMC), The University of West Florida. This tool is built as a distributed knowledge modeling system that enables learning and collaboration over the Internet. CmapTools is designed to provide knowledge modeling capability and has been used to acquire knowledge for expert systems [7, 8], for institutional memory preservation [24] performance support [8], and potentially, as content for instruction in a course.

An expert knowledge model is structured around concept maps [21] that are elicited from an expert in a knowledge domain. A model typically contains a general, top-level concept map, and a hierarchical structure of more detailed maps that elaborate the concepts in the top-level map. The various concept maps are tied together by links between concepts that occur in more than one map.

This knowledge modeling approach further augments the concept maps with text, graphics, audio, video, links to Web pages, etc., that are associated with concepts.

Figure 1 illustrates components of a knowledge model that pertains to the topic of weather forecasting on the U.S. Gulf Coast. A concept map that organizes the knowledge model is the window at the top in Figure 1. It contains the concept "Gulf Coast Region Weather Forecasting," which is the topic of the map and of the model. The concepts in the map are populated with icons that indicate the presence of the accompanying media that elaborate the concept. In addition to providing links to other media such as text and graphics, the icons provide links to other concept maps that contain the concept in other contexts. Learners can freely browse through this media-rich model in order to learn about the knowledge domain.

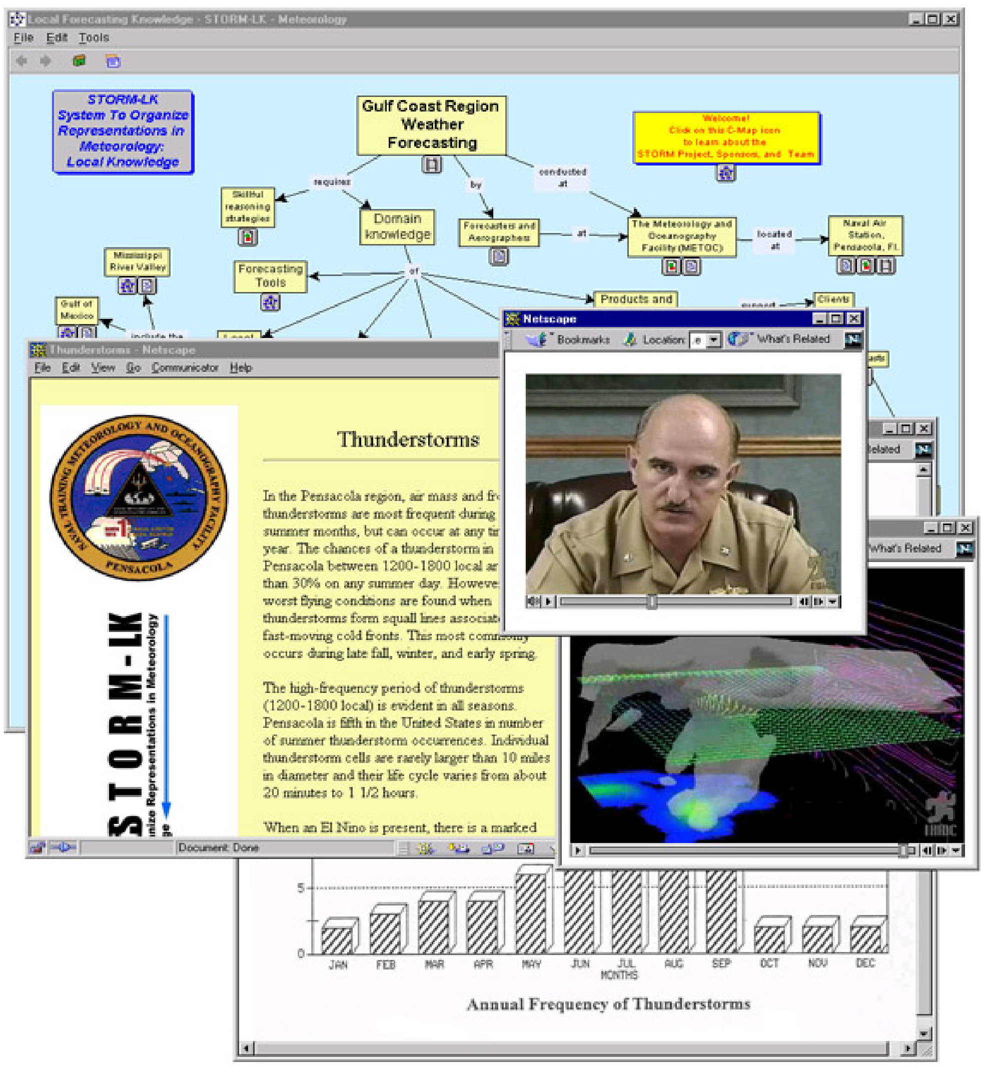


*Figure 1*. A depiction of a Knowledge Model created with CmapTools.

Figure 1 depicts the results of browsing through information on thunderstorms, including a textual description of thunderstorms in the Pensacola area, a chart that presents thunderstorm frequency, a four-dimensional (3-D plus time) animation of thunderstorm development, and a video of an expert discussing thunderstorm formation in the region. Instructional content of the sort shown in Figure 1 can reside on any machine that is configured with the CmapTools server software. The CmapTools client program (which may be configured to include the capabilities provided by LEO) may access these resources from any machine with access to the Internet. The system supports editing knowledge models locally and storing resources on the local machine or remote servers. Other Web-based content such as Web pages can be accessed from the CmapTools client.

Although a knowledge model built with CmapTools has a high degree of internal structure, the models often grow quite large, and contain a large volume of information. If it were deemed desirable for students to learn systematically about some subset of the information contained there, an organizer can be created and presented with LEO, in order to provide guidance regarding what to learn first, necessary prerequisite relationships among topics, or competencies that would indicate mastery of the material. LEO affords a high degree of flexibility in providing guidance to the learner regarding how to approach learning about the content in a knowledge model. Furthermore, the

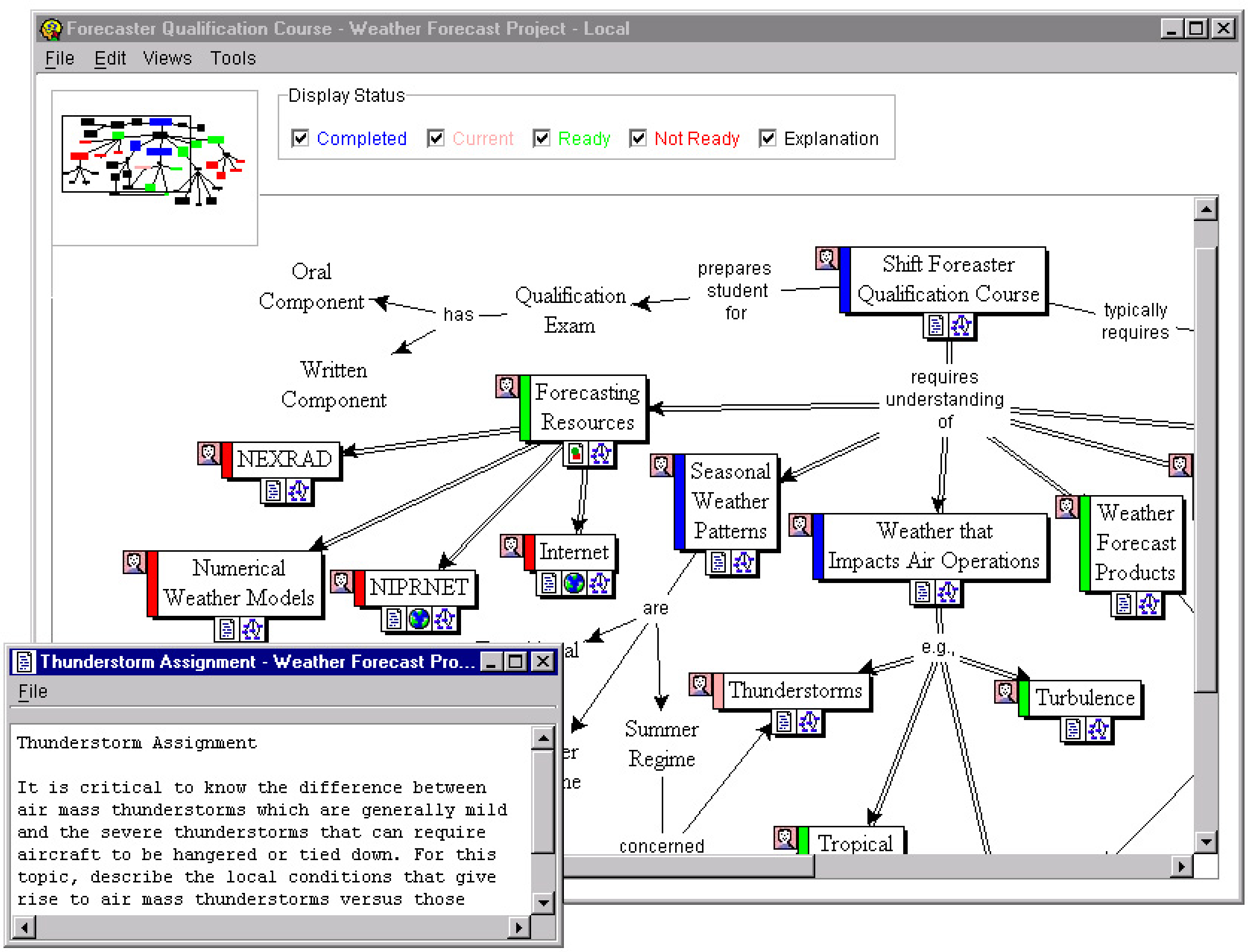


*Figure 2.* The Organizer as the user would see it, showing topic and explanation nodes.

program enables the instructional designer to reorganize a course of instruction quickly and easily in order to support a specific learning goal.

## The Learning Environment Organizer

This section describes LEO's basic functionality and an organizer's look and feel. Figure 2 presents an organizer pertaining to a qualification course regarding local weather effects that must be understood to perform weather forecasting in the Pensacola, FL region. A course organizer takes the form of a graph, a combination of nodes and arcs. The display contains two different types of nodes, instructional topics, and explanatory nodes that provide additional information regarding the topics. The topic nodes have color codings to indicate student progress through the course of instruction. The system presents both a global (context) view and a local (focus) view of the course structure, and a Display Status Panel that allows the user to show or hide subsets of the organizer graph. These features will each be described in more detail in the next sections.

### *Topic/Explanation Nodes*

Topic nodes correspond to the topics in the course. Figure 2 depicts topic nodes as those surrounded with shadowed boxes, populated with icons, and containing a rectangle that color-codes the status of the topic. For example, "Forecasting Resources," "Seasonal Weather Patterns," "Thunderstorms," etc., are topic nodes. The topic nodes are linked together by thicker lines that convey prerequisite relationships. The topic "Shift Forecaster Qualification Course" is the introductory topic for the course. The introductory topic or topics are easily identified since they have no incoming lines that would indicate prerequisites. Explanation nodes elaborate the relationships among the topic nodes and have no adornments.

Figure 2 contains a depiction of the look of the Forecaster Qualification Course organizer as a student works on the "Thunderstorms" topic. The icons beneath the topics indicate links to the instructional content that can be used to learn about the topic under consideration, and to descriptions of the tasks or activities associated with the topic. The icon that looks like a text beneath the topic "Thunderstorms" was selected to open the "Thunderstorm Assignment" window that is in front of the organizer window in Figure 2. The icon that looks like a concept map indicates a pull-down menu with links to one or more concept maps in a knowledge model that relate to that topic. As an example, the student might have navigated from the Thunderstorm topic in the organizer depicted in Figure 2 into the concept map containing information on thunderstorms portrayed in Figure 1.

Links within an organizer may be made to locations in a knowledge model created with CmapTools or to any other online instructional media. As an example, the icon that looks like a globe indicates a link to a Web page. When the user selects that icon, a Web browser is launched and the user is taken to the URL. If course content had already been created with Web pages, LEO could be used to organize it. An organizer can also link directly to textual media (as indicated by the assignment window in Figure 2), to graphics, and to other applications such as simulation software, spreadsheets, databases, etc.

The topic nodes in an organizer are color coded to indicate the student's progress. There are separate, configurable colors for all the various status states a topic can have: *completed*, *current* topic, *ready*, or *not ready*. When a topic is completed, the system changes the color code to the color that indicates *completed* status and then determines which subsequent topics are to be changed to *ready* status. The student using the Organizer depicted in Figure 2 has completed the introductory topic to the course, the "Seasonal Weather Patterns" topic and the "Weather that Impacts Air Operations." The student is ready for but has not commenced the topic on "Forecast Products" and the survey topic on "Forecasting Resources," but is not ready for the details on the Internet and NIPRNET.

The instructor can specify the criteria for completion of a topic. Several possible alternative criteria have been identified and implemented. The instructor may require a submission of a deliverable that must be evaluated before indicating that the topic is completed. The student could be assigned a test (true/false or multiple choice) that is taken and graded on the spot by an automated process, with the Organizer updated immediately. A third completion criterion leaves the decision regarding when to continue to the next topic to the student.

### *Other Features*

A highly articulated organizer with many topics and a large number of explanatory nodes can grow very large and tangled, and does not fit in its entirety on a computer monitor. A concern that the design of this software addresses is the need of the user to see the entire Organizer while still being able to read a portion of it. A basic focus and context scheme has been chosen as an information visualization solution to this problem [25, 26]. The context view of the Organizer appears in Figure 2 as the small rectangle in the upper left corner of the window. It is important to ensure that the context view remains associated with the focus it contains [25]. For this reason, the context view is implemented as a floating palette inside the Organizer window. The focus is the large rectangular component that fills most of the window. The context view contains a rectangle that corresponds to the visible portion of the window in the focus. The focus view can be scrolled along arbitrary trajectories by dragging the small rectangle around the context view.

Figure 2 also illustrates the Display Status Panel, the small rectangular panel in the top-center of the graphic, which allows subsets of an Organizer to be shown or hidden. To ameliorate the potential problem of putting too much information in front of the student at once, nodes of any given status (*completed, current, ready, not ready*) may be either shown or hidden. In addition, the explanation nodes may be shown or hidden. The check boxes associated with a given node status may be selected or deselected to show or hide that subset of an organizer. The colors of the words indicating status in the Display Status Panel correspond to the color codes associated with the nodes themselves. For example, the word "completed" in the Display Status Panel is color-coded blue. As instructional topics are completed, their color codings are changed to blue to reflect the progress.

### *Login - registration and authentication*

Students can freely browse through the Organizer itself and can follow the links to any of the instructional content at any time. If they wish to work on a course with the Organizer, they must first be registered with the system and log on. Once the student has logged on, the system either retrieves the progress record associated with the userid and the particular organizer for which the logon occurred, or it creates a new progress record for the given organizer and userid. The progress record contains information on the student's progress, submissions of deliverables, whether the deliverables have been evaluated, etc. When the student initiates the process of setting a topic to *completed* status, the system manages the process. If the student has the prerogative to update the status of a given topic, the system automatically updates the screen display and the student progress record.

A separate application program enables the instructor to query a database that holds the student progress records in order to check for pending assignments that students have submitted. The application the instructor uses checks the progress records of each student, looking for ones that require evaluation and update. The progress record has a field that indicates the need for the update. The instructor's software checks the progress records for the students, determines which ones have submission evaluations pending, and provides the capability to annotate the student progress record with the results of the evaluation.

***Uses of Organizers***

Course organizers can be used in several different ways. An organizer can be used as the organizing factor and homepage for the delivery of a synchronous or asynchronous distance learning course. An organizer can be served from a CmapTools server on which student records reside. Students can work on the course and the instructor can query student records anytime from anywhere. Difficulties inherent in the exclusive use of purely distance learning methods have given rise to efforts to create and present hybrid courses in which the instructor and students meet face-to-face periodically, and the student works some percentage of the time at a distance. A solution based upon an organizer is ideally suited for such applications. Finally, an organizer can play a significant role in face-to-face classes by presenting an advance organizer for the course, fostering negotiation of goals for the course, and serving as a repository for a rich collection of instructor and student-generated materials.

## An Example Organizer

Figure 3 depicts an example Organizer that has been created for a course in Data Structures and Algorithms. The linking icons have been omitted from the figure to foster readability of the example. It is important to note that Figure 3 presents one possible version of an organizer for this course, but another instructor might conceive of a different course organization. A substantially different organization of the course could be created that could still utilize the same learning resources that are used in any other version of the course. Further, if an instructor wished to modify the structure of the course, editing in LEO would make the changes simple to realize.

The example organizer was produced by an iterative process in which three different versions were created. Figure 3 depicts the final version. Although the example evolved through several iterations, early versions revealed some interesting characteristics. From the earliest version, the organizer made explicit the two major dimensions of the course, "Data Structures" and "Algorithms." It was obvious how these two dimensions related to the major course topics by reading the topics linked to the "Data Structures" and "Algorithms" explanatory nodes. It was evident that the major data structures are arrays, lists, trees and graphs, and the major algorithms involve creating data structures, adding and deleting elements, searching and sorting. Many more details regarding how these superordinate concepts interrelate can be gleaned from the explanations.

The final version of this example organizer contains 16 topics and 31 explanatory nodes. The media accompanying the topics are comprised of textual descriptions of the structures and algorithms, textual code examples of the implementations of the data structures, and graphics illustrating how

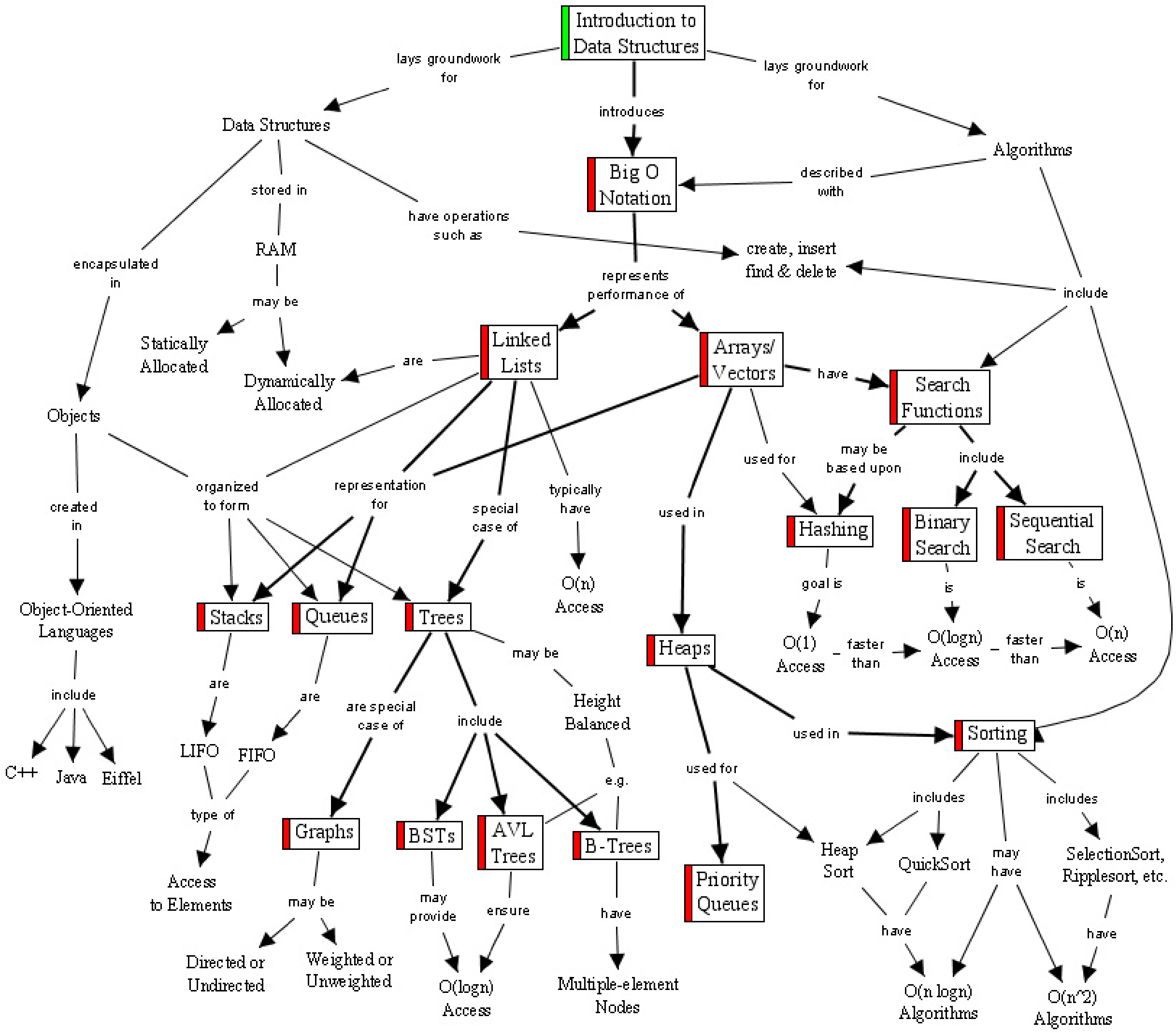


*Figure 3.* The Data Structures Organizer.

the data structures are manipulated. A measure of redundancy exists between the information presented in the explanatory nodes and in the course content itself. The difference is that the organizer presents all the general knowledge in an easily understood global view that presents the interrelationships among the topics. As a reinforcing factor in learning the knowledge domain, this redundancy is judged to be a positive attribute of the approach.

This course contains and depicts a number of topic dependencies that are critical to overall understanding. As an example, it is important for the student to understand the basics of arrays and linked lists before going on to the next topics. Therefore, this sequencing of topics was necessary. The sequence in which these two topics are learned are not particularly critical, and the organizer illustrates that fact. Although the course contains a total of 16 topics, the longest path length in the course is 4. A sequential arrangement of topics would yield a path length of 15. This Organizer presents a good example of taking a course that is typically taught in a linear sequence, making it significantly less linear, and presenting a conceptual view of the relationships among the topics. This global representation of the entire course can be studied undertaking mastery of the details. Furthermore, this mapping of only the necessary prerequisite relationships among topics increases the efficiency with which a user can prepare for a specific needed topic.

## Summary and Conclusions

This work describes LEO, a software tool that supports a new approach to creation of computer-mediated learning environments that are based upon the idea of advance organizers, and that are designed to foster the development of conceptual knowledge. An organizer created with LEO potentially provides a higher degree of learner control while delivering instructional content anywhere at anytime. Organizers can be used to support distance learning course delivery, hybrid delivery with a face-to-face and distance component, and to augment a face-to-face presentation. An organizer created with LEO provides the student with a graphical representation of topic sequences in the course, explanatory information regarding the topics, and completion criteria. The system tracks the student's progress through the topics in the course. This approach is illustrated by an organizer for an online course in Data Structures and Algorithms.

The principal goal of rendering a course in an advance organizer is to foster the development of integrated structural knowledge. Learners are presented a well-integrated conceptual view of the course structure and content rather than a linear listing of course topics with no indication of how they interrelate. This global, conceptual view fosters the development of a general framework for the course within which the learner can integrate new ideas and progressively differentiate details. If an organizer is used with a knowledge model of the sort created with CmapTools, the content already has internal structure, and the organizer is essentially a metacognitive tool. The best course organizations created with LEO are designed in such a way that students will be minimally constrained in the choices they make regarding topic sequences, educational materials they access, and the like.

A course organized in this fashion can increase learner control in at least two ways. First, it presents many possible paths through the topics. Students are able to progress at their own pace and along their own paths. Also, an organizer can facilitate the negotiation of learning goals with regard to the amount of emphasis placed on specific topics. For example, if an organizer pertained to artists of a certain epoch, the student could peruse a global view of the domain, browse materials pertaining to the various artists, and negotiate with the professor the goal of learning about a specific artist.

An organizer also has significant utility to support just in time learning for performance support. The fact that a well-constituted organizer maps only those prerequisites that are necessary to an understanding of a given topic ensures that a worker who requires support for a specific task can develop sufficient background to perform the task without having to work through other extraneous material. This approach contrasts markedly with the typical textbook or reference manual that has references to topics interspersed throughout. The user must look at each occurrence individually to determine if it contains salient information. Such a search is time-consuming. Even if the user does find the needed information, the foundational knowledge necessary to understand the information may also be interspersed throughout the text. An organizer presents a different organization that makes the prerequisite knowledge and the topic itself easier to identify and learn.

This approach can be used to present any sort of course organization from one that is entirely linear and sequential, to one that is completely non-linear. If the content is best taught as a linear sequence of topics with evaluations at every step, such an arrangement can be made. It can still be augmented with the explanatory information that fosters greater understanding of the structural knowledge of the course rather than simple memorization of details. If the course of study involves a more conceptual approach, an organizer can be used to create an explicit conceptual representation of the domain and to give a high degree of control to the learner in terms of what to do next and when to move on to the next topic.

Employing this approach does not preclude any of the traditional face-to-face or distance learning strategies. Students who collaborate could negotiate what to do next or even negotiate with the facilitator the completion requirements for a topic or the entire course of study. Within this capability, the designer's conceptual model of the domain guides the instruction. Students are free to develop their own models of the domain. The only constraints that are imposed are those that the instructor deems necessary in order to pursue the goals of the course.

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