Implementing Cognitive Learning Strategies in Computer-based Educational Technology: A Proposed System

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ABSTRACT

Switching the development focus of computer-based instruction from the concerns of delivery technology to the fundamentals of instructional methodology, is a notion that has received increased attention among educational theorists and instructional designers over the last several years. Building upon this precept, a proposed methodology and computer support system is presented for distilling educational objectives into concept maps using strategies derived from cognitive theory. Our system design allows for a flexible and extensible architecture in which an educator can create instructional modules that encapsulate their teaching strategies, and mimics the adaptive behavior used by experienced instructors in teaching complex educational objectives.

INTRODUCTION

For decades, research on computer-based educational technology in medicine (and in the rest of the educational milieu) has focused on efficacy. The literature abounds with studies that present authoring systems, user interfaces, navigational structures and testing schemes designed to improve student performance and enhance learning. Most of the research statistically demonstrates a modest gain in test scores for students using computer-based learning tools in comparison with students using traditional forms of instruction.[1] Compelling arguments by Clark however, have shown troubling inconsistencies and methodological flaws in studies and meta-analyses on media and learning.[2] Clark contends that it is instructional design methods not delivery technology which influence learning. In the following statement, he attributes the research problem to a "confusion of technologies":

> Instructional or training design technologies draw on the psychological and social-psychological research to select necessary information and objectives (as a result of task analysis), and to design instructional methods and environments that enhance achievement. A very different technology – delivery technology – is necessary to provide efficient and timely access to those methods and environments. Both technologies make vital but very different contributions to education. Design technologies influence student achievement.[3]

Assuming Clark's argument is accurate, another research predicament is posed. Were pedagogical methodologies, not delivery technologies, to become the focus of research in computer-driven education, we would then need to define something far more ambiguous, namely what defines an effective learning theory. Unfortunately, a veritable labyrinth of conflicting hypotheses in both the education and psychology domains have prevented the realization of conclusive guidelines. Instructional designers, therefore, are left to the task of synthesizing competing theories into a workable framework that reflects the objectives, and perhaps biases, of a given educator.[4]

This leads to yet another paradox. If there is no conclusive understanding of what a good learning paradigm is, than how do we assess a viable educational strategy for learning, and specifically, learning with media? This is problematic, especially in a field such as academic medicine where, to a large extent, educators are teaching based on breadth and depth of clinical and scientific experience as opposed to being trained in educational theory. The question then becomes, is it appropriate to expect medical educators who are interested in exploring the educational value of media to become familiar with the intricacies of theoretically driven instructional design? The answer is, probably not.

So what is the solution? By changing the focus of computer-based educational design from the culture of delivery to the more esoteric aspects of learning theory, instructional designers can provide innovative tools for cultivating effective teaching strategies. Educators contributing their knowledge and experience can draw upon these resources to create a modular infrastructure that can expand and evolve as the instructional application develops. This paper is an attempt to formalize a methodology and computer-based system for achieving the objectives described above.

MAPPING COGNITIVE LEARNING STRATEGIES

Instructional designers are faced with the daunting challenge of melding the contributions of cognitive science and educational technology into a refined learning environment. Recent developments in cognitive psychology have provided increased understanding of the learning process, while simultaneous technological advances have pushed the capabilities of instructional design (ID) far beyond its early beginnings.

It would be premature to suggest that there is clear understanding of the learning process, however cognitive learning theory has brought to light several significant concepts.[5,6] First, the learning process seems to be quite individualistic and varied. Second, knowledge is structured and refined by experience and use. Third, new information is best learned by integration into a prior knowledge base. Lastly, knowledge is retained with both contextual and environmental cues.[7] Attention to these factors has led many to revise their thinking on ID theory.

Traditional computer-assisted instruction (CAI) has generally focused on the presentation of content, and often fails to impart the valuable experiential knowledge of an instructor. Accomplished educators often have multifaceted approaches to communicating complex concepts to students, continuously gauging comprehension and metaphorically "switching gears" to clarify deficits in understanding. It is this aspect of instruction, which needs to permeate CAI. By providing tools that allow educators to impart some of their "thought process" into the design, we have the potential to enhance the computer-based educational process, as well as the overall learning experience for the student.

In order for this instructional design to be effective, an educator must have clearly defined learning objectives. The scheme outlined in Figure 1 subdivides a single learning objective into three major groupings: domain knowledge, skill set, and method. Domain knowledge refers to the minimum background needed for comprehension of the learning objective (with supportive knowledge acting as cues); skill set is an assessment of required cognitive abilities for this objective; and method encompasses the educators "teaching strategies".

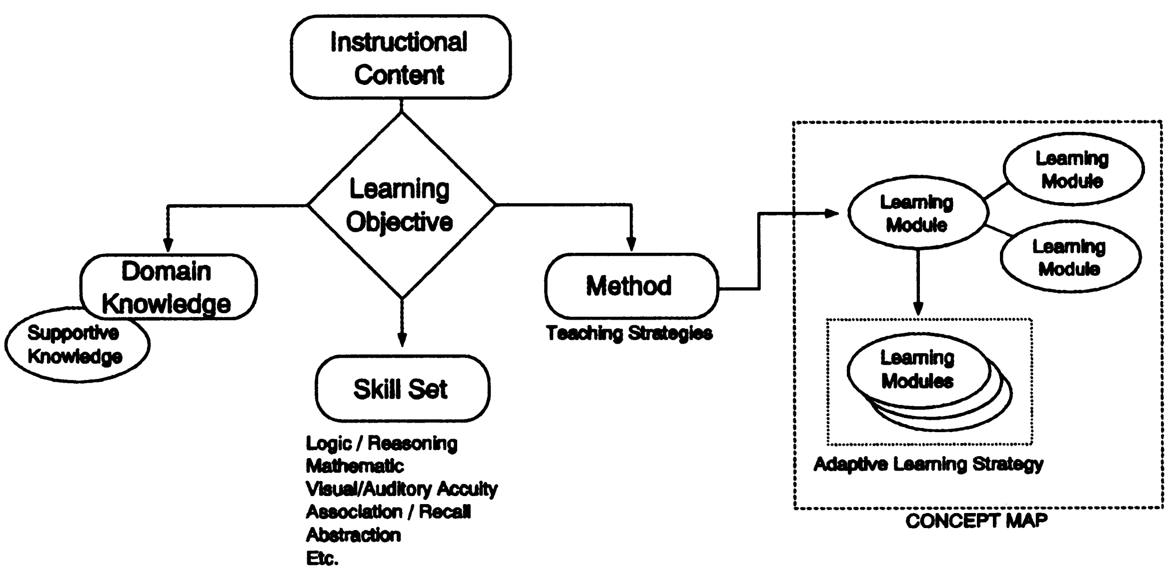

Figure 1. Scheme for the development of Concept Maps

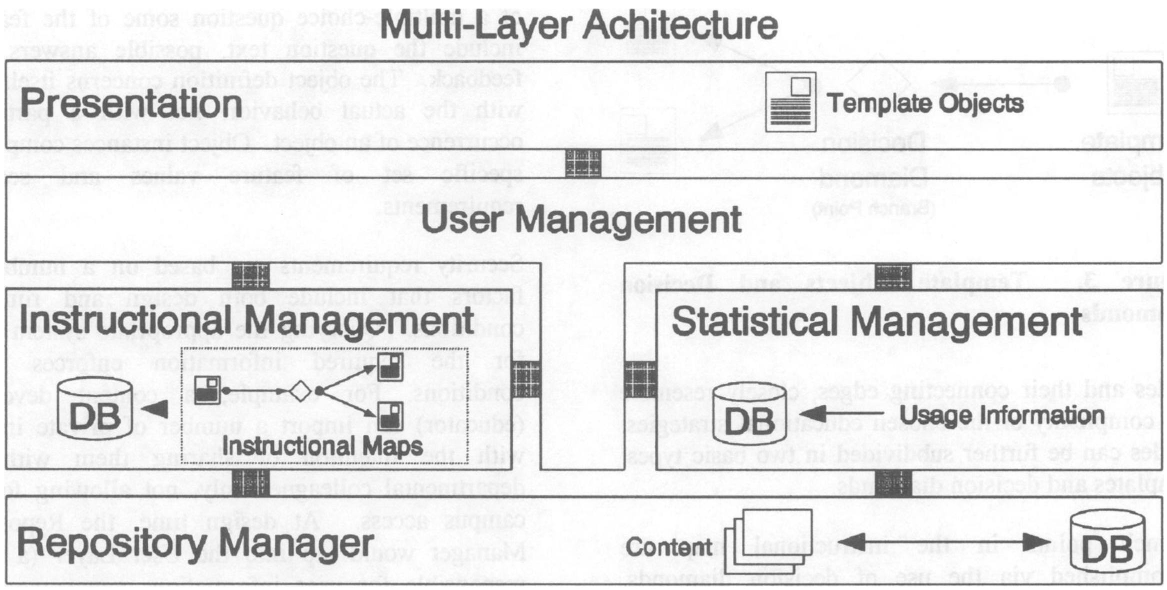

Figure 2. Scheme for system design

The method section is a construct the educator uses to guide the learner through a network of learning modules. These modules are created by the educator and have specific instructional prescriptions. Borrowing from the ideas set forth by Tennyson et. al., learning modules can be classified into three general types: expository, practice, and problem-oriented strategies.[6] Expository to presents ideas, concepts, rules, facts, and principles; practice to develop procedural knowledge; problem-solving to establish cognitive skills. Tools provided to the educator allow for the encapsulation of specific thought and logic steps. By linking modules together, a flexible and extensible framework can be created (hereafter defined as a Concept Map).

To achieve an adaptive behavior, learning modules can also be grouped based on content presentation. This structure allows for multiple views of a single instructional element. Utilization of statistical tracking and weighting allows these grouped modules to act as "adaptive learning strategies" thus providing the educator with a way to switch gears and better illuminate the learning objective.

The instructional content can have numerous learning objectives each having a distinct concept map. The overall instructional design is dictated by this collection of concept maps, referred to as an instructional map below.

DESIGN CONSIDERATIONS

The broad realization of learning modules as tools for educators is contingent on the creation of an expressive medium under which they can fully exploit and utilize teaching strategies. Such a system should be able to capture the uniqueness of their teaching styles, and benefit from the capabilities of computer technology to guide the end-user. As illustrated in figure 2, the proposed system is composed of five layers – Presentation, User Management, Instructional Management, Statistical Manager, and the Repository Manager. The layers interact with each other in the manner described below.

The educator begins by linking a series of concept maps, creating an instructional map, which is a tree-like representation of the instructional design. The Instructional Management Layer provides a set of advanced software tools that allow educators to visually represent, manage, and author instructional maps.

As illustrated in figure 3, the tree representation begins with a single entry point, which can branch into a series of paths. These branches, comprised of

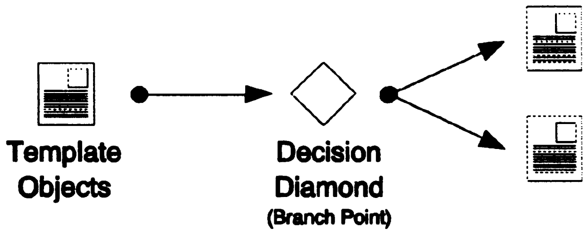

Figure 3. Template Objects and Decision Diamonds

nodes and their connecting edges, closely resemble the complexity of the chosen educational strategies. Nodes can be further subdivided in two basic types: templates and decision diamonds.

Branch points in the instructional map are accomplished via the use of decision diamonds. Decision diamonds are a set of condition/action pairs, where actions are executed only when the respective condition is "true". These actions redirect end-user navigation thus providing further learning support. Conditions may include either basic or complex operations. Complex operations require the use of statistical manipulations, carried out via the Statistical Management Layer. Based on statistical data, educators are able to assess the learner's (end-user) logical progression, and modify the course of instruction. Statistical data is collected throughout end-user's navigation of the tree.

Template objects are the visual elements presented to the end-user, populated with information obtained from the Repository Manager. These objects graphically represent instructional items such as multiple-choice questions or slide images. The educator uses a supplied collection of objects to populate the instructional maps. Use of pre-fabricated templates greatly reduces development time, and allows for concentration on the module's structure and usability. In addition, end-users are provided with a consistent interface. Templates also facilitate the creation of information repositories, by providing educators with a gateway into a central data warehouse.

The Repository Manager is responsible for the organization, definition, and storage of educational elements (such as graphics and text) and their associated access operations. The object definition bundles together all aspects of specific educational elements. Each element possesses unique features that capture the essence of that element. In the case of a multiple-choice question some of the features include the question text, possible answers, and feedback. The object definition concerns itself only with the actual behavior, not with a particular occurrence of an object. Object instances comprise a specific set of feature values and security requirements.

Security requirements are based on a number of factors that include both design and run-time conditions. Querying the appropriate system layer for the required information enforces these conditions. For example, a content developer (educator) can import a number of private images with the intention of sharing them with his departmental colleagues only, not allowing for off campus access. At design time, the Repository Manager would tap into the User Layer (a layer responsible for user information management) to obtain information about the particular educator intending to use the image in question. At run-time, it would query the Presentation Layer (responsible for the visual interface) to enforce in-house use. The Repository Manager also deals with logical organization of object instances. The access operations provide the necessary hooks for object instance retrieval used by other layers, verifying that the security requirements are not violated.

The User Management Layer deals with the profile information, such as first name, last name, department, password, etc. Based on this information, instructional content can be designed with two parallel paths, with the same information presented at two different levels of detail. For instance, one level for medical students and another for residents, each user navigating the appropriate path.

The Presentation Layer handles the on-screen presentation and delivery of template objects; it is made up of a series of modules that implement the end user experience (i.e. the look and feel as experienced from the end-user's viewpoint). The design provided by this layer allows for the rapid incorporation of new delivery environments, such as the World Wide Web.

DISCUSSION

Concept mapping of cognitive learning strategies is an instructional tactic that has the potential for significantly increasing educators effectiveness in the classroom and in designing computer-based educational technologies. From the educators perspective however, the requirement that each instructional objective be meticulously planned could be considered in both positive and negative terms. Thoroughly dissecting a lesson plan gives an educator the rare opportunity to rethink teaching strategies, become more familiar with instructional objectives, and perhaps develop a better understanding of student learning behaviors. On the other hand, the time and persistence that such an undertaking requires is far from trivial.

The system we have proposed was designed specifically to support concept mapping. A map can be as linear as a drill and practice slide box, or as complex as a problem-based learning example. Ideally, educators will use the system to augment and refine their teaching strategies as they get accustomed to the fundamentals of concept mapping. In the early stages of the development process, support for educators can be provided by an instructional designer familiar with both the process of designing teaching strategies, and with the various learning behaviors demonstrated by students.

In order to realize its full potential, a system such as the one proposed requires a fundamental paradigm shift within the academic environment. The current model of education at most institutions has students attempting to inculcate mass amounts of didactic information, often at the expense of "true" learning.[8] Educators must break with traditional teaching practices which emphasize unstructured rote memorization and impart to their students not just what to learn but how to learn it.

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