

SmartTutor: Combining SmartBooks™ and Peer Tutors for Multi-media On-Line Instruction

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Danny Kopec completed his undergraduate work at Dartmouth College obtaining a degree in Psychology modified with Math (1975). His Ph.D. at the University of Edinburgh, was in Machine Intelligence (1983) with a thesis entitled *Human and Machine Representations of Knowledge*. There, under the supervision of Donald Michie, he first learned about “advice languages” and knowledge engineering. At the University of Maine (1988 –1992), Dr. Kopec helped develop the SmartBook paradigm which was subsequently implemented for AIDS education, for a “Rules of the Road SmartBook” to help US Coast Guard Cadets learn ship navigation rules (1995), and most recently at Brooklyn College (Summer, 2001) for delivery of CPR. Dr. Kopec’s general interest is in identifying the knowledge necessary for expert performance.

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Paula A. Whitlock received her Ph.D. from Wayne State University in engineering where she studied elementary combustion systems using computer modeling. Subsequently, she joined the Courant Institute of Mathematical Sciences at New York University where she worked on the development and application of Monte Carlo methods to solve the Schroedinger Equation for ground state and finite temperature systems. Since joining the Computer Science faculty at Brooklyn College in 1990, Professor Whitlock has studied parallel pseudorandom number generators and continued Monte Carlo investigations of quantum mechanical systems. She has also been active in improving the undergraduate computer science curriculum.

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Myra Kogen is the Director of the Brooklyn College Learning Center, which has a national reputation in the field of collaborative learning in a college setting. Learning Center projects have been funded by the U.S. Department of Education, the National Science Foundation, the Fund for the Improvement of Post-Secondary Education (FIPSE), and the Howard Hughes Medical Institute. Kogen's Ph.D. is in modern American literature, and she has written on writing across the curriculum, peer tutoring, and college composition. She is an advisory editor of the *Journal of Basic Writing*, and is co-editor of *Dialogue on Writing: Rethinking ESL, Basic Writing, and First-Year Composition*, a collection of articles recently published by Lawrence Erlbaum.

Abstract

SmartBooks is a comprehensive, multi-media educational technology that was developed just prior to the emergence of the World Wide Web. This technology has provided a user-friendly, self-paced, up-to-date, easy to modify, and comprehensive software environment geared to the learner's needs.

The SmartBooks technology has lead to the development of a new system, SmartTutor, that facilitates a multi-media, web-based peer-tutoring service geared to urban commuter college students. A model for the student creation of the web site is discussed as well as the ongoing evaluation of the emerging software for the project.

The assessment of the usefulness of the site is just beginning and its development is an ongoing process. We believe that consistent experimentation with iterative refinements will lead to an effective website for delivery of peer tutoring. In time, this approach will also lead to a more sophisticated intelligent system.

Introduction

The Brooklyn College Learning Center has had a long history of providing effective on-site peer tutoring for an urban college campus in New York City. Brooklyn college is a four-year liberal arts institution whose students are a blend of many cultures and languages: 38% speak English as a second language, 70% receive financial aid and many are the first in their families to attend college. These students are often highly motivated but they need help to achieve their goals. At Brooklyn help is provided by trained undergraduate tutors who assist students in understanding course concepts and assignments. Each year about 4000 of the College's 15,000 students visit the Learning Center to work with their peers on assignments in writing, mathematics, science, and the twelve required core curriculum courses. However, a serious problem has developed in that demand for help has exceeded the Learning Center's ability to provide assistance. Budget constraints limit the number of tutoring staff that can be hired and the number of hours that the Learning Center can be open. Brooklyn's commuter students, most of whom work many hours to support their college education, need additional help available at the times when they are free to address their coursework.

The solution to these problems has been the development of an interactive website that offers information about on-campus Learning Center programs and selected tutoring services on-line^[1]. On-line tutoring is not intended to replace peer tutoring, but to work hand in hand with it by creating customized out-of-class instruction on the web for students. Our new approach for offering on-line tutoring involves the use of SmartTutor, a multimedia, educational technology based on the SmartBooks system first developed more than a decade ago^[2]. SmartTutor innovates in its use of the heuristic technique of concept mapping^[3] designed to enable the individual learning preferences of each student user. The user reinforces his understanding of new information by navigating through the web-based material. The system is designed to meet the needs of students who have different levels of understanding of course content. Of major importance in the development of the

SmartTutor system is the input of peer tutors, students, faculty and advanced computer and information science majors.

Background

SmartBooks, which is the foundation for SmartTutor, provides a technique for allowing users to navigate through complex domain specific material in a non-linear fashion designed to meet their own cognitive stages. The model has been used in the last decade for the development of prototypes of educational software for sexually transmitted diseases including AIDS^[2b] and training materials in navigation for U.S. Coast Guard Academy Cadets^[4].

The driving force of the SmartBook approach is the use of “concept mapping,” which has been demonstrated to be a sound paradigm for learning and education^{[5][6]}. Concept maps are a graphical form of knowledge representation whereby all the important information in a domain can be embedded in hierarchical information nodes and links (connecting the nodes). At any time during the use of the system a user can view how they arrived at where they are (the path taken through the SmartBook) and where it can lead. This is indicated by a pictorial representation on the top of each section illustrating how the shaded circle (node) was reached and what circle(s) (nodes) it can lead to. This is shown for one section of the AIDS Smartbook in figure 1.

Unlike static conventional textbooks where the traversal is sequential, rigid and unchangeable, an advantage of a SmartBook is flexibility, the fact that it can be developed for any domain using a sound educational methodology and that it can be used and traversed in many ways. The order in which material is covered is the choice of the user. In essence, the SmartBook represents a road map through a knowledge base. Transparency in form and function is fundamental to SmartBooks. In addition to existing pop up windows, there is the potential for linking to a glossary of terms, synonyms for key words, a retrace facility, expert advice, and video-based presentation of graphical information. As any good knowledge base, it is easy to modify,

expand, and refine. Figure 1 illustrates some of the standard SmartBook features.

SmartTutor

SmartTutor applies all the useful, student-learner oriented features of SmartBooks in a web-based environment. We are currently planning the design of SmartTutor for a number of domains which can be applied to the undergraduate curriculum. Modules for courses in Computer Science, Biology, Mathematics, Physics, and Social Science are being constructed using essentially the same paradigm we have detailed above. The new technology provides instant access for the student at all times to the tutoring facility. It is intended to provide *all* students with access to the best possible content, not just those students with the most talented tutors and to provide an alternate path for students who may otherwise be too intimidated to seek help.

In addition, the more intelligent a tutoring environment is about the domain it is trying to educate about, that is the more domain-specific expertise the systems embodies, the more effective it will be. For example, excellent baseball video games know everything that needs to be known about the subtleties of the baseball environment, including the rules, the playing fields, the idiosyncrasies of the players, etc. The same is true for effective educational environments. They must have rich and deep domain knowledge and be able to ask the right follow-up questions of the learner in order to deliver effective instruction. They must embody rich multimedia-based curricula, assimilated tutoring knowledge, and have the ability to assess the level of the learner. They must know how to test, evaluate, and improve the knowledge of the learner. The aim of the SmartTutor system is to capture and mimic the knowledge and the experience-based intuition of the effective teacher. In this case, the peer tutor working with faculty members and senior computer science students provides the knowledge base.

In education it is accepted that the more an environment approximates reality, the better it will serve. Advances in hardware and software facilitate the production of more effective virtual environments. Automated environments which fail to exploit such

possibilities will always be open to the criticism that the learner is “just reading text.”

Sound, animation and other multi-media techniques enhance the system’s ability to reinforce student understanding. Color can be employed to help distinguish diverse aspects of the educational system, including, for example, to represent issues of urgency, tempo, danger, comfort, risk, etc.

In our implementation of the SmartTutor system, the student, upon entering a particular course tutoring site, is presented with a concept map which graphically represents the relationships between basic course topics. This is illustrated by Figure 2 for a Computer Science course in the C programming language. The student can enter the material at any node (students come for tutoring with different levels of subject knowledge). Once students have entered the system they can choose their own path through the material by referring back to the concept map which records where they have visited. For example, they can go from “The *for* loop” (Figure 3) to “The *if* statement” and back and see in the map the record of their visits. At any point, the student can query the database about keywords and concepts or visit links for further information. If a student loses her way, she can return at any point to the original concept map and view where she has been. A student can return to an already-visited node without having to follow the whole path back. An innovative feature of SmartTutor now under development is that students will be able to give themselves a self-test at any time, based on their particular subtree (path) of learning through the SmartTutor site. The quiz can refer learners back to the appropriate sections of SmartTutor where the relevant material is presented. There is also a comprehensive self-exam which can cover the entire SmartTutor material giving students can feedback on their performance automatically.

Developing SmartTutor Materials

The model that we are evolving to facilitate the addition of new SmartTutor domains, employs the pairing of an advanced computer and information science (CIS) undergraduate working on a senior project with a master (peer) tutor for the course. The peer tutor is

responsible for identifying the key material that students request assistance with. Since additional material can always be added, the initial development focuses on the areas that students claim are most difficult. The CIS student then transforms the tutor's material into a concept map for the domain. The two work closely together to design the appearance and the content of the nodes within the domain. Implementation is the responsibility of the CIS student doing a senior project supervised by a CIS faculty member. New ways to carry out tutoring are discussed at group meetings and input is regularly solicited from the larger community at Brooklyn College.

It is important to note here that to prepare an effective SmartTutor system requires the input of a number of major college constituencies—in this case students, tutors, faculty and computer experts. The purpose of the Brooklyn College Learning Center web site is not to replace instructors but to assist students who are having trouble and need extra help. Peer tutors are considered the experts on student learning since they have had considerable experience in identifying the concepts that are giving students the most difficulty, but faculty have deeper understanding of course content. Early in the development of SmartTutor packages, peer tutors consult extensively with faculty. For example, a recent preparation of a concept map for the college's core curriculum course in physics (required of all students) had to be modified when physics faculty disagreed with the tutors' analysis of how topics should be categorized. The faculty members suggested that inertia and kinematics be split into two separate sections. On the other hand, tutors were aware that students often have difficulty distinguishing between conservation of energy and conservation of momentum, so they decided to alter the original concept map to help students solve this problem. Then when advanced computer science students work on the SmartTutor system, decisions are made about formatting, basic design, associating information, and highlighting of key words that correspond to database entries, in addition to such decisions as whether to include animation and sound. And finally the packages must be tested by student users in order to identify potential strengths and problems.

At our on-line tutoring website, the basic web pages are programmed in HTML. We

are using MySQL, an open source SQL database system, that the college had installed for use with Blackboard. Most interactive activities are implemented using the PERL scripting language. Also, database access from the webpages is carried out via PERL. Javascript and PHP are also used when necessary to provide animation and other multi-media features.

Future Developments and Assessment

The Brooklyn College Learning Center project aims to: 1) design an on-line tutoring program that recreates the advantages of person-to-person tutoring and works hand-in-hand with on-site services; 2) create effective on-line tutoring strategies that support the learning needs of non-traditional urban students; 3) make use of faculty, peer tutor and student input to design a program that reflects institutional needs; 4) continually assess and revise the program so that it will be useful and usable; 5) create a prototype that other institutions can use to develop on-line tutoring programs that suit their own needs.

Site usefulness is always a major concern^{[7][8]}. According to Davis^[9], though lack of human friendliness can hinder user acceptance, perceived usefulness is not primarily about design choices—it's about cognitive understanding and retention: "No amount of ease of use can compensate for a system that doesn't do a useful task." As more content is added to the web site, more formal testing and evaluation will be done. Focus groups of students in the targeted courses will also be formed to more thoroughly evaluate the usefulness of the site.

Our aim in creating SmartTutor is to give students the feeling that they are filling gaps in their knowledge, that they have a greater ability to move forward in a class, that they have more understanding of how successful students approach difficult problems. If SmartTutor can provide these things then that would be a real mark of success. It is important that SmartTutor's effectiveness as a learning tool be carefully tested and evaluated. We can give pretests and post-tests evaluating subject matter knowledge. For

example, performance of students in courses delivered with and without the SmartTutor (which can reside on the web with a special course password) would be one way to measure their effectiveness. Traces of nodes visited can also be helpful in evaluating learning styles of the students using SmartTutors.

Evaluation will also examine whether students who use SmartTutor return to use it again, whether certain webpages seem to be more effective than other pages, whether the on-line program works hand in hand with on-site tutoring, whether students, tutors and faculty feel it sufficiently supports coursework, and, eventually, whether students who use the on-line system perform better in gateway courses than those who do not use tutoring services, use only on-site tutoring services, or use a combination of both services.

The SmartTutor system is designed to formulate a model for an on-line resource that will support students working at their own initiative and out of their own interest to integrate and synthesize knowledge and methodology outside the classroom. The model combines collaborative learning techniques (social interaction, access to peer tutors) with SmartBooks technological advances (individualized learning paths, coaching controlled by the learning) to create an integrated package for the student. While the goal of providing 24/7 tutoring for core curriculum and other courses has not yet been fully achieved, much has been learned and the web site is viewed as an ongoing experiment that can only become more comprehensive and better with time.

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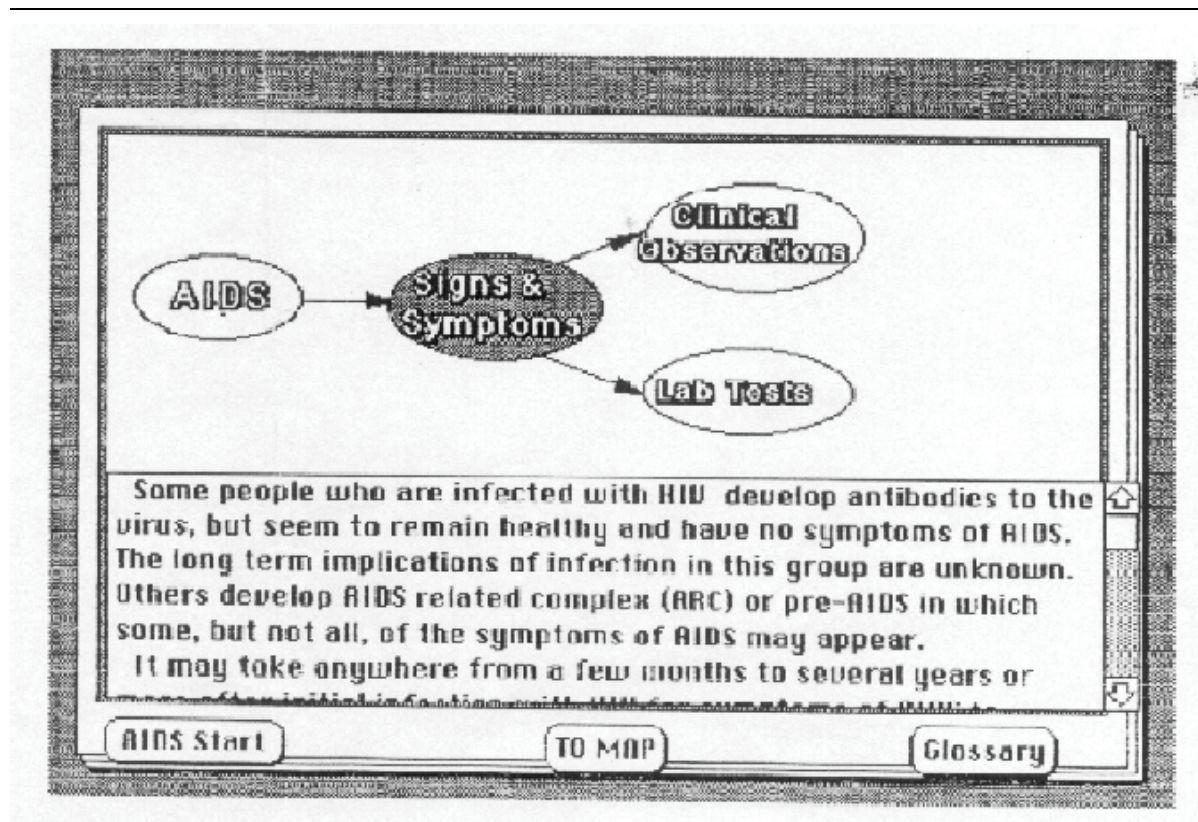


Figure 1 A typical page from the original AIDS SmartBook developed in hypercard for the Macintosh in 1992^[2b].

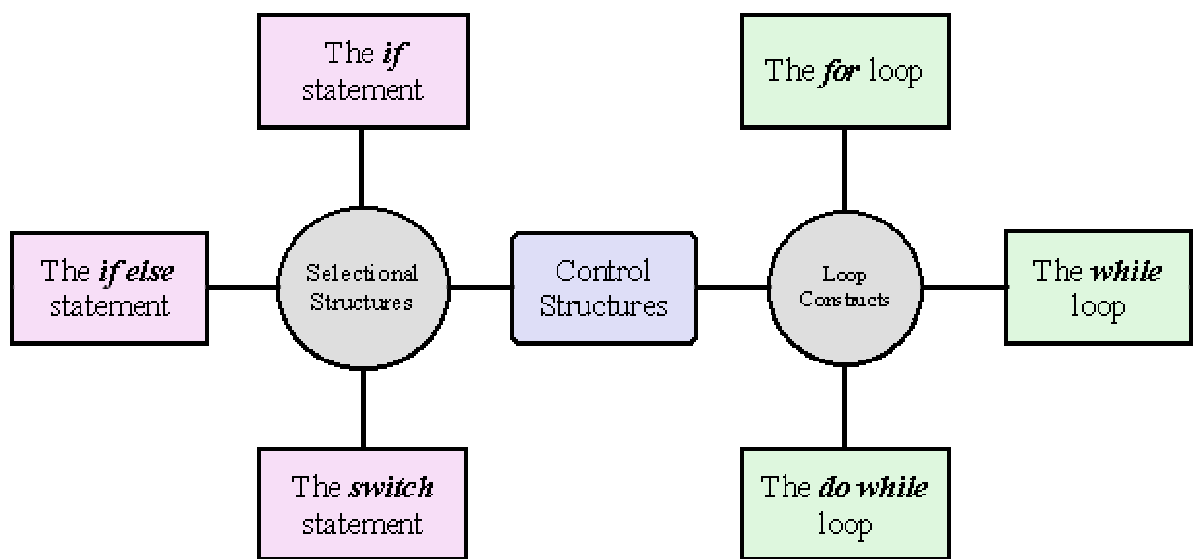


Figure 2 Concept map of some topics on the introductory C programming language SmartTutor prototype. This map distinguishes between the various control structures available in the language. A user clicks on one of the nodes to obtain further information on the topic.

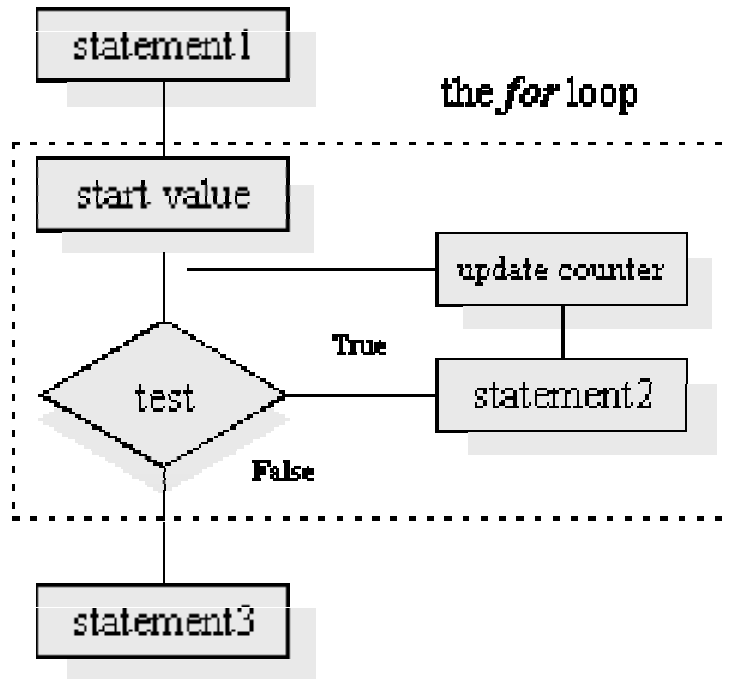


Figure 3. Example of the *for* loop node from the SmartTutor concept map from the introductory C programming system. In addition, there are animated traces of for loops on the webpage.