Lowering the Lifecycle Cost of Training via Networks

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ABSTRACT

A chief advantage of computer networks is the integration of resources and processes. While computer- based training has been around for decades, issues such as computer security and heterogeneous machines have posed barriers to the effective integration of training systems. Recent and emerging standards for networks offer an opportunity to dramatically reduce training costs by increased integration. We present an architecture for an integrated training system by levering such standards. A cohesive training system is particularly crucial for military training. The stringent cost, time and mission requirements of military training are exacerbated by the geographically dispersed and culturally diverse training audience.

This paper examines how existing database, World Wide Web software, and multimedia tools can be combined in a common framework to facilitate an integrated training environment. This environment, provides capabilities such as: integrated course registration, automated grade reporting, sophisticated personnel profiles (e.g., for tailoring materials presented and integrating reporting), eased courseware configuration, integrated testing and fully automated grading, automated remediation, integrated mechanisms for student feedback and collaboration, and context-sensitive help and multiple levels of materials explanation. Application of these factors promises to dramatically reduce the cost and improve the of offering a large number of training courses compared to their paper-based counterparts..

ABOUT THE AUTHORS

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INTRODUCTION

Training is a multi-billion dollar per year Army expenditure. The Army's Training and Doctrine Command's TRADOC Pamphlet 525-66 notes important advantages of employing network-based training mechanisms for cost-effectively providing instruction. This paper presents our innovative approach for authoring and delivering training over the computer and communications networks.

Central to producing cost-effective training are two central themes from engineering: reuse and process integration. This paper discusses work done using traditional and knowledge-based approaches and techniques for authoring training. The knowledge-based approach incurs an up front cost, but one which is handsomely paid for in terms of reusable materials. Process integration also requires an initial outlay, but also offers a dramatic cost reduction.

This paper discusses the development of authoring tools designed specifically for delivering multimedia instruction over the World Wide Web (WWW). Such considerations are critical for effective delivery: multimedia streaming and hybrid delivery are not sufficiently robust for delivering instruction. The fundamental resource limitation of the network technology is bandwidth; if authoring and delivery tools do not force the author to consider bandwidth, then networks will be overwhelmed for the foreseeable future. Further, network-based training reduces cost, but without offering the guidance of a human instructor; instruction must be enabled to assess and adapt to each student's needs. This paper discusses our measures for providing tailored tutoring while conserving bandwidth.

Network-based training also poses a variety of security problems. Government WWW sites are favorite targets for information warfare and the training itself may be of a sensitive nature. Authentication issues are also raised: one must ensure that users are who they say they are, or at least cannot masquerade as someone else. Confidentiality, authentication, and system integrity are important issues for network-based training. We will provide a cursory treatment of our security measures in this paper as well.

This paper is organized in the following fashion. First we provide some background on the specific training problem. Within this background material, we describe previous efforts at Computer-Based Training along similar lines and the administrative processes involved in offering the training. We then present our approach for delivering network-based training. Specific aspects of the system, and of people's using the system are then described. We then perform a brief analysis of the financial impact of using the system. Finally, we draw some conclusions and describe the anticipated direction of our work.

BACKGROUND

Network-Based Training

Network-based training mechanisms promise to revolutionize training. Distance learning mechanisms enable offering synchronous (i.e., lecture style) training over large geographic distances. World Wide Web (WWW)-based mechanisms facilitate asynchronous (i.e., correspondence style) training at high quality levels. Such WWW-based mechanisms typically have been viewed as offering relatively static training at a significantly lower cost.

These mechanisms can be combined to offer a hybrid-style of training, while integrated distributed resources to address other aspects of offering training.[1] Such other mechanisms include:

1. Automated course registration, grade reporting and student review,
2. Automated organization and dissemination of materials,
3. Integrated remediation,
4. Tailoring of training materials,
5. Tutoring of students, and
6. Collaborative interaction among students.

These mechanisms tradeoff the requirements of having databases and knowledge bases integrated with the system in exchange for (1) reducing the logistical burden of delivering courseware (A, B, and C) and (2) improving the quality of the training offered (C, D, E, and F). The specific implementation of these is discussed under the approach section.

Integrating the databases and knowledge bases pose one particularly stringent requirement: security. There are numerous aspects requiring security within such a system. Materials must be physically secure and protected from tampering. Students' identities must be validated. Performance must be accessible for review, but on a dynamic basis. Sensitive training subjects and billing for training only complicate the matters. We present a thorough description of one security aspect - that of administering examinations - in the approach section.

The Specific Training Problem

Our starting point for network-based training was converting the Combat Service Support's (CSS's) Battalion Materiel Management Officer (BMMO) CBT for operation over the Internet. The materials converted discussed the process of arming and fueling battalion-level forces. The original CBT was generated as part of the SIMITAR[2] project. Converting the materials to run under Microsoft's Internet Explorer™ and Netscape's Communicator™ avoided several types of problems encountered when using materials created using CBT tools, such as crashing Windows when the user's computer was not a duplicate of the designer's system.

The first goal of our work was to exactly duplicate the original CBT, both its good and bad points (Figure 1). The Scimitar project assumed a particular computer configuration, including a 2x CD-ROM. One of CSS's "lessons learned" from offering CBT was that pre-positioning CD-ROM's was a logistical nightmare. A preliminary focus of our work was to develop methods to simultaneously accommodate both CD-ROM based materials (where available) and downloadable network-based materials. A small number of such changes made the system far more flexible; it now runs on virtually any computer with any kind of network connection. A derivative result was understanding the bandwidth-quality trade-offs and interactivity characteristics of various audio, video and graphics formats (Table 1).

Once we duplicated the Scimitar project's materials, we were charged with demonstrating the limitations of network-based training. The path we took with the training materials was to illustrate how well they could be adapted to the user to (1) maximize training effectiveness while (2) minimizing authoring costs. We now describe our approach for accomplishing these goals.

APPROACH

The initial converting of the training materials was done largely via the HTML editor in Netscape's Communicator Gold. It also necessary to develop some hand-coded HTML, Javascript, Java, and Common Gateway Interface (CGI) programs to fulfill unique requirements. The CGI programs enabled the database functionality for course registration, student identification, examination grading, etc. These materials can be viewed from www.WiseWebWare.com, provided that they are accessed from outside of a firewall; cookies[3] (and other techniques) are used, which are often blocked or destroyed by firewalls. The following sections describe the approach used to move beyond the simple duplication of materials for improving effectiveness and minimizing costs.

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[1] D. Goldstein and J. Goldstein, Hybrid Tutoring: a New Paradigm for Instruction, submitted to IEEE Internet Computing, IEEE Computer Society, Los Alamitos, CA.

[2] SIMITAR is a DARPA-sponsored project supporting the National Guard Enhanced Brigade's training and operations. The materials referenced are from the Combat Service Support team at Camp Dodge.

[3] Cookies enable knowing the state of a person taking the lessons. Cookies are very small pieces of text which are sent between a site and a user. A cookie can only be read and modified by the particular site that created it.

System Architecture

Figure 2 depicts a high-level view of our system architecture. The components of the architecture can be broken down into several basic types of components with distinct characteristics.

- Viewers enabling the dissemination and presentation of multimedia. Material dissemination, which is a huge cost of offering correspondence courses, is dramatically eased by network-based training. Sophisticated server products for disseminating formats to certain viewers are required in some instances. However, streamed audio and video are *insufficient* to address asynchronous training: their effectiveness is inherently tied to the simultaneous viewing of instruction by multiple participants.

- System administration tools for ensuring the consistency of databases, configuring multimedia materials, guaranteeing security, etc. Because such materials are not incorporated within existing CBT tools, multimedia is sometimes duplicated 10 or more times.

- Hybrid delivery mechanisms to address the huge files often incorporated into multimedia training. However, the pre-positioning of materials counters one of the chief advantages of network-based training - the trivial dissemination cost. Hence, the architecture uses knowledge-based agents to reduce the sizes of such multimedia files where required. A short mantra also assists in designing effective network-based training: **entertainment is not education.**

- Database managers perform routine tasks on databases which typically comprise much of the expense of everyday activities. Course registration, grade reporting, performance analysis, etc., are widely held uses of databases in current educational environments. Effective database management can provide additional functions for network-based training which offer huge cost-savings. Such functionality includes materials configuration, version control and reuse. **Constructing multimedia is the overwhelming cost of computerized training, so reusing multimedia dramatically reduces the cost of developing such training.**

- Knowledge-based agents assisting the authoring of training materials. Current Computer Based Training authoring tools offer little to no support for ensuring pedagogically sound instruction. "Internet-based training" versions of tools are almost always inefficient (if they even work); tools sold for building shopping mall kiosks are also being marketed for CBT. **Instructional designers are inherently biased towards a particularly sensory mode, and, therefore, type of multimedia.** Unless your students want to wait 10 minutes while a movie or audio clip loads, this bias typically must be addressed by an external agent - whether human or machine. This bias is somewhat mitigated, without any loss of pedagogical value, by our agents which reduce bandwidth requirements by selecting more efficient multimedia formats (Table 1).

- Knowledge-based agents for tailoring of (stand-alone and embedded) instruction. Knowledge-based agents can tailor training to each student's background to provide a number of key advantages. Training can already be tailored and explained (at run-time) to compensate for reading comprehension and mathematical aptitude. Future tailoring will include automated translation to a variety of languages.

- Traditional and knowledge-based agents for reusing materials across training domains, as knowledge in decision aids, as parts of control systems, etc. Reuse of multimedia and knowledge can - by themselves - reduce the cost of systems by approximately 90%.[4] Once a graphic is created, there is no need to create 40 similar graphics simply because tools traditionally do not support configuration. Similarly, our knowledge encoding a BMMO's relationship to an XO can be used to train the BMMO, train the XO, assist in completing forms, judge error rates for performance, etc.

We now present one aspect offering the training, in detail, in order to illustrate the system's behavior.

Secure Testing

One of the most difficult problems associated with network-based training is delivering examinations. In fact, without removing the advantages of network-based training altogether, there will always be minor opportunities for breaching security. This section

[4] K. Cennamo, Layers of Negotiation, in Educational Technology, 36(4), 1996, pp. 39 - 48.

describes the process involved in authoring and delivering examinations which guarantee the authenticity of the participant and guarantee the integrity of the student's answers to some extent.

The process of authoring an examination (Figure 3) involves filling out a template of an exam. The process also requires indicating the candidates for answers on any particular section of the examination (for multiple choice-type questions) and specifying the types and ranges of parameters for word-problem type questions. The exam template (Figure 4) incorporates items such as instructions which can be tailored. The questions and answer parings for multiple choice questions can be specified in several ways. However , one should limit the number of pieces of knowledge from which to select the items to a small domain. Further, the set of items should include a reasonable mix of objects, i.e., a form should be offered with forms as opposed to a form, a vehicle, a container, and a procedure. The types of parameters for word problems are very varied, enabling different numbers of parameters in word problems, sizes of numbers (i.e., to make arithmetic easier or more difficult), and of different probabilistic distributions (e.g., binomial, Gaussian, etc.)

The delivery of the examination over the network is as follows. First, whenever a student accesses any materials he provides an identifying number. Passwords can be trivially added to this identifier. Materials are tailored via a profile, contained in a database, who's key is the user identification number.

The examination page is created at run-time from the template. When exams are generated, a file is created on the server to ensure that the student cannot cause the randomly-generated questions to be recreated differently. The individual questions are created in the following manners.

- Multiple choice questions are created by randomly examining pieces of knowledge and selecting a correct answer among the alternate choices. Several alternate choices are also offered. Please note that true/false and matching-type questions can be subsumed within matching-type questions.

- Word problems are generated by scanning the word problems for variables. The variables are created according to a probability distribution, a numeric range, and a precision. These values are substituted in the word problem for the variables and the results are noted internally to the system.

One should note that the process for authoring pre-tests and exercises is identical to that of examinations. However, pre-tests and examinations are delivered with explanations to the user, i.e., a question and its answer will automatically be restated upon request by a user. Also, pre-tests and exercises can offer automated remediation; some kinds of pre-tests automatically create links to the supporting WWW pages describing the concept.

The security of administering tests is difficult to ensure, both in live testing and over networks. Our approach is approximately as secure as placing a lone student in an unsupervised room. While we could take measures to reduce the student's access to electronic mail, external telephones, etc., such measures are beyond the scope of the effort. We are satisfied that the randomly generated examinations are simply more secure than the static ones currently used in correspondence courses.

Sample materials can be viewed at www.WiseWebWare.com.

RESULTS

The training materials and tools delivered to the Army were designed to minimize cost and installation requirements. Hence, we employed the same WWW server, database managers, etc., as currently in use at Combat Support Services. We also integrated links to the Army Training Distance Library (ATDL) within our materials and anticipate our work being incorporated as a demonstration within ATDL.[5] We intend for almost all of the administrative and authoring functions to be integrated within the WWW browser environment.

Economic Analysis

The costs of offering training over the World Wide Web can be categorized as infrastructure and recurring costs. The infrastructure costs are largely one-time charges, including the cost of networks, authoring tools, and delivery tools. The recurring costs, including system administration costs, equipment maintenance, and software updates.

The one-time costs can be estimated in terms of training servers, communications lines, classroom computers, authoring tools, and delivery tools required. "Back of the envelope" calculations indicate that these costs will be approximately.

[5] The Army Training Distance Library can be found at http://www.atsc.army.org/atdls.html.

These first costs are for each training server, including software. Note that these will not actually be incurred once, but will entail obscelecence. Assuming three-year depreciation, this involves approximately $460,000 per year. There will also be a monthly $1,000 cost for a T-1 line from the server, bringing the total to $472,000. Courseware must be created, entailing following costs.

ITEM	COST
WWW Server-software	$800
Streamed audio ten-person version	$500
Knowledge-based tailoring and delivery agents	$4,000
Communications line-T-1	$3,000
Server hardware	$5,000
Database managers	$500

Cost per server: $13,800 x 100 servers = $1,380,000

Assuming that thirty instructional designers are required to support the Army's range of courses, the recurring costs amount to $3.5 million per year. Hence, we estimate yearly program costs of approximately $4 million per year. Assuming an additional ten system administrators are required at an approximate level of the instructional designers, yields a cost of $5.4 million per year.

ITEM	COST
Yearly cost of instructional designer	$55,000
Benefit/organizational cost of instructional designer labor	$55,000
Yearly cost of the designer's computer	$2,000
Yearly cost of the designer's software	$1,500
Yearly communications line costs	$2,400

Cost per instructional designer: $115,900

These costs must be compared to that of offering correspondence and on-site training courses. Correspondence courses can be summarized as follows:

Item	Cost
Yearly cost of instructional designer (including benefits)	$55,000
Benefit/organizational cost of instructional designer labor	$55,000
Yearly cost of the designer's computer	$2,000
Yearly cost of the designer's software ?	$1,500

Cost per instructional designer: $103,500

However, correspondence courses are far less likely to reuse materials - since the configuration must be performed by hand. Assuming a (very conservative) level of one time duplication of effort would yield sixty instructional designers to be required, at a cost of $6.1 million.

Course materials must also be supplied on an individual basis. Assume that the following courses are associated with each course:

ITEM	COST
Cost of course materials	$50
Cost of ten postal mailings	$20
Logistical costs of course registration, grade recording, etc.	$50

Cost per course: $120

If we assume that 100,000 courses are taken per year, this cost amounts to $12 million. Further, assume that there is an additional one-tenth as many courses which must be taken in person whose needs could have been fulfilled by interactive lab experiments, animation, etc.

ITEM	COST
Cost of course materials	$50
Cost of travel	$1,000
Cost of full-time student labor devoted to training[6]	$500
Logistical costs of course registration, grade recording, etc.	$50

Cost per course: $1,600

These costs amount to another $16 million dollars. This costs total approximately $28 million of training costs per year. The cost of network-based training, at approximately $5.4 million per year is a bargain in comparison.

Quality of Training

[6] Many commercial and military personnel have indicated that network-based training is often completed in fifteen - twenty minute intervals of "down time". In contrast, shipping a soldier to a base to receive training obviates that person from performing any other activity.

Network-based training should not only be more cost-effective, but entail qualitative improvements as well. The network-based training mechanisms enable collaboration and remediation in an unprecedented manner for remote instruction. By tailoring training to individual students, a situation (e.g., mission essential task list, tailored training such as delivering food in Kuwait, as opposed to England), and resources, the intelligent agents enable optimizing the materials to maximize performance. Intelligent Tutoring Systems, such as those developed here, have been repeatedly been experimentally shown to be more effective than more traditional training mechanisms.

Knowledge-based training over networks also offers a number of other important advantages. Not the least of these is offering embedded training and integrating distributed resources (such as decision aids). The interested reader is encouraged to examine other works on how these same techniques could be utilized for embedded training.[7]

CONCLUSIONS AND FUTURE WORK

Network-based training provides numerous advantages over traditional methods for non-school training: training can be offered any where, at any time, with integrated remediation and better interactivity than can be provided via paper-based courseware. Our approach for integrating various logistics aspects of providing courseware even further reduces the cost of offering training. Such integration provides an integrated framework for numerous personnel matters (e.g., testing, training, promotion, decision aiding). Our current work aims at dramatically improving the effectiveness of training while reducing costs.

Our current work addresses providing tools for authoring learner-centered Intelligent Tutoring Systems (ITS). The knowledge-based approach to ITS enables a variety of operational advantages, including multi-lingual training, wrap-around training, and a wide range of remediation capabilities.

TRADOC 525-66 indicates the Army's commitment to distance learning and network -based training. Our work has provided a framework for powerful capabilities for user-tailored training.

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[7] D. Goldstein, *Ramifications of HLA-Compliance for Knowledge-based Simulations,* 1997 Fall Simulation Interoperability Workshop, Orlando FL, September 8-11, 1997.

Sound Format	"Compression" Ratio of a Sample File	Comments on Interactivity
PCM 11,025 Hz, 8 bit	2:1	Full interactivity; no quality loss
ADPCM 8Khz, 4bit	4:1	Full interactivity, noise in high frequency spectrum
Real audio	10:1	No autoplay capability; less interactive
MSN 8Khz, 8bit	11:1	Full interactivity, slight quality loss
PCM 8 KHz, 8 bit	23:1	Full interactivity, moderate quality loss

Table 1: Sample Sound Format Performance

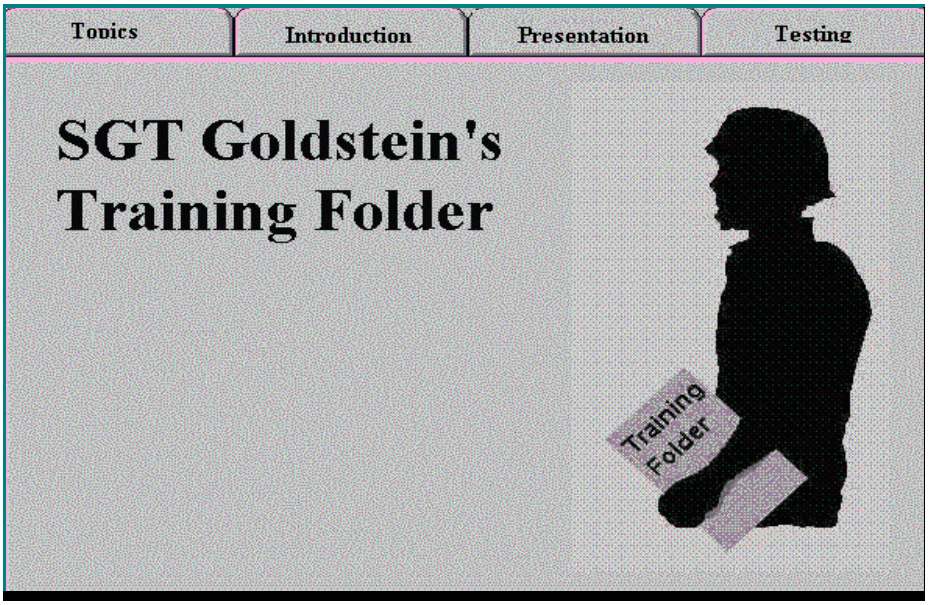

Figure 1: Tailoring Instruction to Individual Students on the WWW

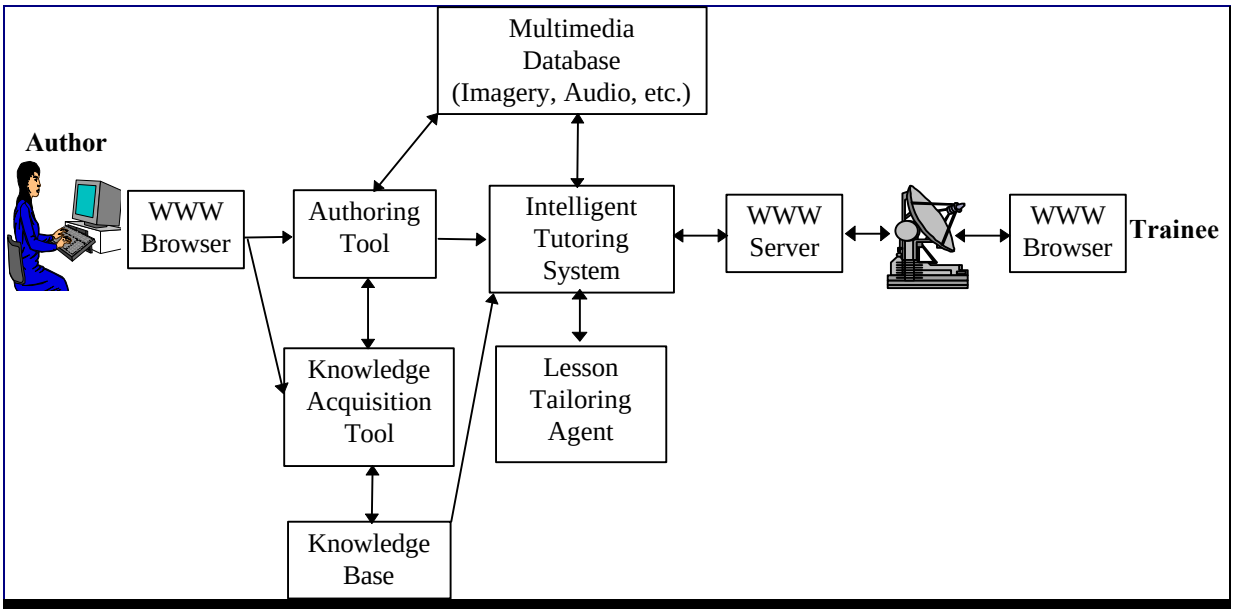

Figure 2: Condensed Version of the Architecture

This condensed version of the architecture provides a high-level view of our work. A more detailed description is provided with our overheads at the talk and www.WiseWebWare.com.

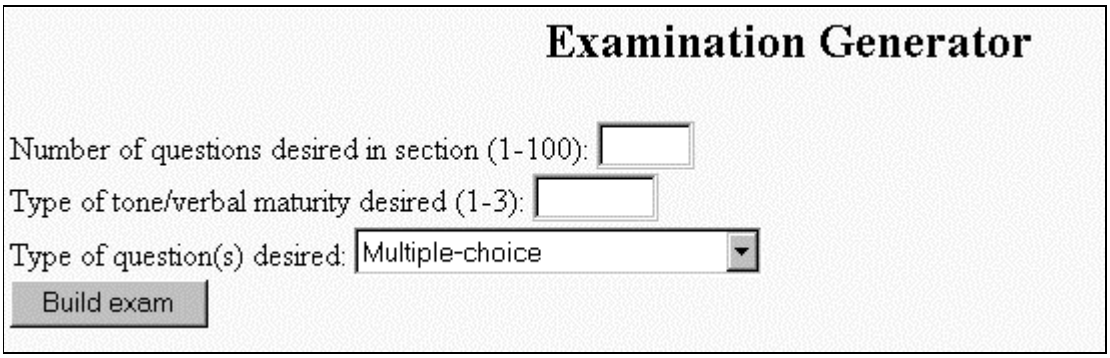

Figure 3: Authoring Exams over the WWW

```
; Exam objects have a number of questions which have been asked, and a
; number of correct answers.  The number of items actually generated depends
; upon the aptitude of the student (to keep the exam challenging)
(defclass examination (is-a USER)
            (pattern-match reactive) (role concrete)
      (slot num-questions (type INTEGER) (create-accessor read-write))
      (slot num-correct (type INTEGER) (create-accessor read-write))
)

; Each question has text that is created for the basis of the question.
; Each question also has candidate responses, which are randomly
; generated.  Selecting a response has a corresponding effect, which
; includes scoring, creating congratulatory remarks, tutoring, etc.
; Each question also has a correct answer.
(defclass question (is-a USER)
      (pattern-match reactive) (role concrete)
  (slot question-text (create-accessor read-write) (visibility public))
  (multislot responses (create-accessor read-write) (visibility public))
  (multislot effects (create-accessor read-write) (visibility public))
  (slot correct (create-accessor read-write) (visibility public))
 )
```

Figure 4: Descriptions of the WebExpert (WWW-based CLIPS) Question Objects