GROW: A Digital Library for Geotechnical, Rock, and Water Aspects of Civil Engineering

**John Kemeny, Elena Berman, Paul Bracke, Wayne Brent, Muniram Budhu,
Anita Coleman, Ronan Dempsey, Jeremy Frumkin, Maliaca Oxnam,
Leo Przybylski, William Rassmusan
University of Arizona, Tucson 85721**

1.0 Introduction

The web has become an important tool in engineering education. At the most basic level, students view course web pages containing course information and assignments. At a higher level, the web becomes a classroom-like learning environment for online courses. There are a number of current approaches being used for online course delivery. The most common approach focuses on text and graphics, much like a traditional textbook. This approach still has many educational advantages over a textbook, including the ability to use links, the ease of updating material, and instant access to the material around the world. The primary disadvantage of this approach is that it caters to a learning style much different than the traditional lecture: reading text as opposed to watching and listening. More innovative approaches include the use of streaming audio, streaming video, and animation. These approaches cater to the same learning styles of students in a traditional classroom, and can be used in conjunction with a discussion forum to promote interaction. The primary disadvantage to these approaches is the large bandwidth requirements associated with streaming video and animation. This disadvantage can be reduced by the use of streaming audio to replace streaming video and the use of vector graphics and animation (via programs such as Macromedia Flash) to replace bitmap graphics and animation [1,2].

Digital libraries have many similarities with online courses. A digital library is an online source of information about a topic or range of topics. Digital libraries contain a wide variety of media types, ranging from arrays of educational building blocks (text files, images, sound files, video clips, etc.) to complete learning modules that educate the user in a particular subject. Metadata searching is an important element of digital libraries, and useful search engines allow searches for media type, learning outcomes, audience level, rating, etc. Many if not most digital libraries depend on contributors for the building and sustainability of the information. This allows a large, ongoing source of information to be compiled, but there are difficulties controlling the type and format of the information. Like online courses, there are a variety of approaches to presenting material in digital libraries. These libraries are thus susceptible to the same deficiencies as online courses with regard to catering to different learning styles. Also, unlike an online course that is designed for a specific educational level, digital libraries are generally open to users of all ages and educational backgrounds. This presents challenges for digital library developers.

A digital library for Civil Engineering is being developed at the University of Arizona [3]. The initial focus of the digital library is on collections in three targeted areas: geotechnical engineering, rock engineering, and water and its use. The Geotechincal, ROck and Water Engineering (GROW) Digital Library at the University of Arizona is an NSF-Funded NSDL project built on collaboration between campus units. A team has been assembled that brings together faculty and staff from the College of Engineering, the University Library, the School of Information Resources and Library Science, the campus computer center, and the campus teaching center. There are several unique aspects to this digital library. First of all, the library will address specific learning and content needs for a number of different audience groups, including K-12, higher education, professionals and the community at large. This means that a given topic area may be "repackaged" separately for these different groups. Secondly, the collections will utilize modern multimedia techniques to promote active online learning. This includes interactive learning modules rich in animation, video, sound and images as well as an interactive questioning environment. As part of the digital library, a host portal is being developed that will provide easy access to the collections in the three target areas and to allow for the growth of the collection in other areas of civil engineering. An advisory panel is assisting us in various aspects of the library.

This paper describes the GROW digital library. It will focus on the collections aspect of the digital library, both the format for the collections and the specific content in the three areas of geotechnical engineering, rock engineering and water and its use. An equally important area is the infrastructure for the GROW digital library, which provides for the ability to store, maintain, access, search, identify, and use the content of the three collections. These topics are only briefly described in this paper.

2.0 The GROW Collection Philosophy: To Tell A Story

The web is capable of presenting a wide variety of media, including text, images, sound, animation, and video. However, presenting interactive multimedia on the web does not guarantee a learning environment for the viewers of the media. An interactive web activity can be compared with a classroom activity. The classroom activity in isolation would probably be confusing and have little educational value for the student. What gives the activity educational value is the context in which it is placed, and having well defined learning objectives and outcomes. A good classroom activity, for example, will start with an introduction to provide the context. Leading questions may be asked at this time to get students interested in the problem. The activity will be followed by exercises to reinforce what students have learned, and a summary to inform students of the desired educational outcomes. Further challenges (questions, quizzes, etc.) may also be given, and students will then be directed to additional sources of information for outside learning. This allows more advanced students to gain additional knowledge related to the subject manner. Overall, the pre-activity, activity and post-activity exercises do more than just present information; they tell a story.

We are trying to capture the same "to tell a story" environment with the GROW digital library collections. Figure 1 present a storyboard for the smallest self-contained lesson in the GROW digital library, the "learning unit". It consists of six "steps": Intro, Interactive Activity, Reinforce, Summary, Challenge, and Links Out. In the GROW digital library each of these steps will appear on separate html pages.

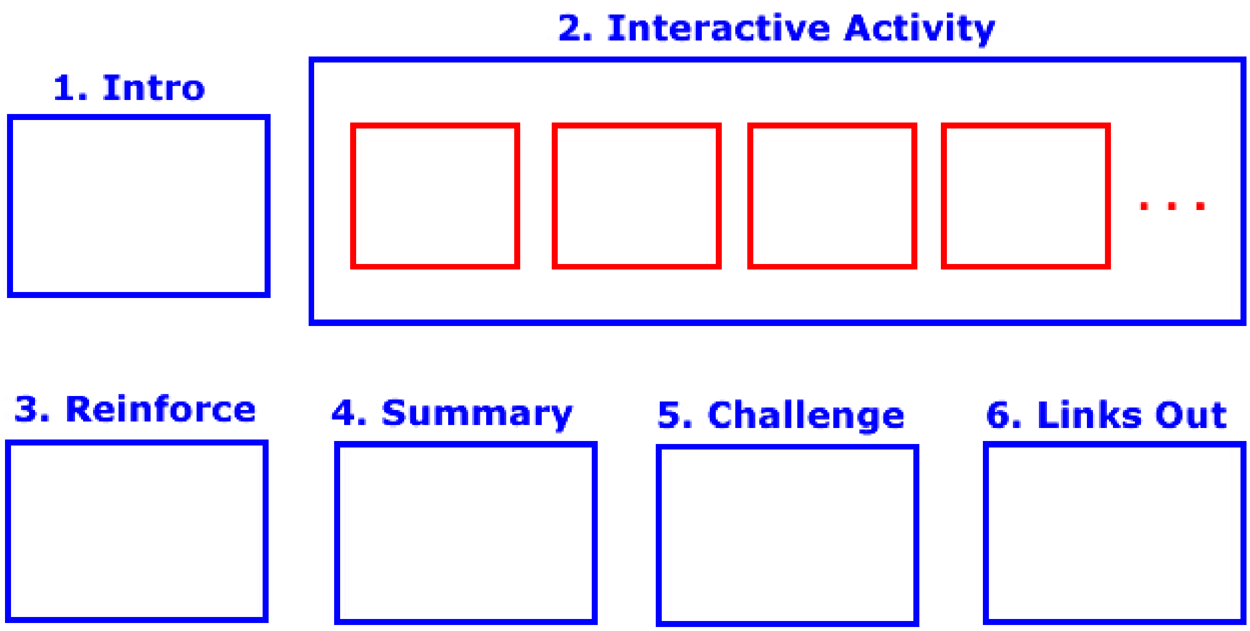

Figure 1. Storyboard for a "Learning Unit", the smallest self-contained learning lesson in the GROW digital library.

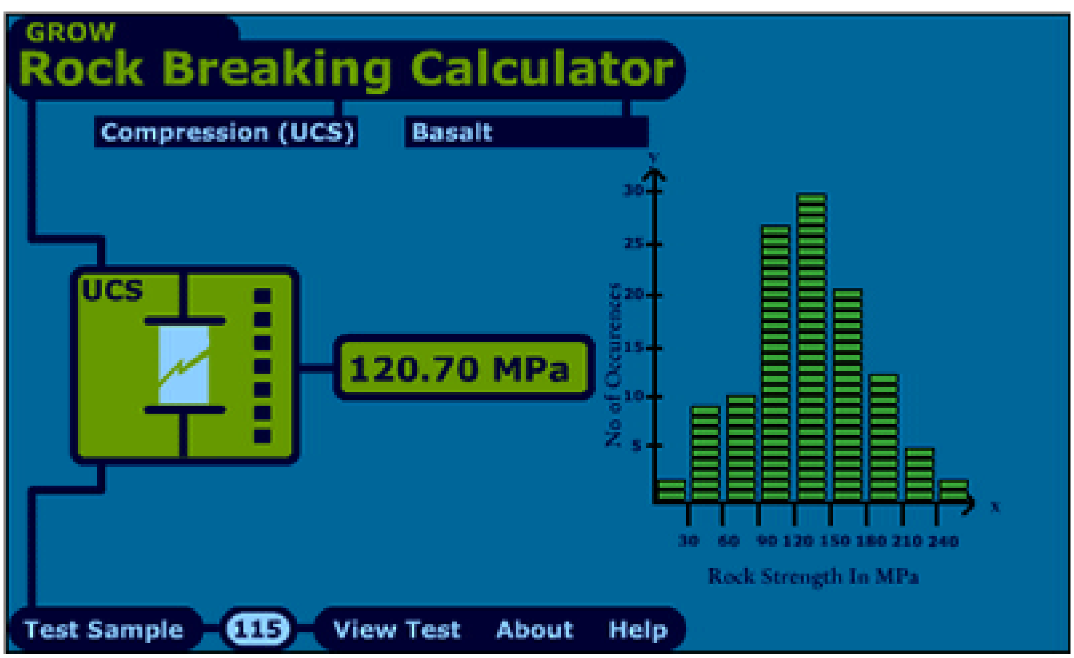

Figure 2. Example of the interactive activity step in the learning unit on the strength of rock. In this example the user picks the type of test, rock type, and has tested the rock 115 times. The resulting rock strength histogram is continually updated as testing progresses.

Each learning unit is centered around an interactive multimedia activity, such as the rock breaking activity shown in Figure 2. These are similar to many such interactive activities found in other digital libraries. What makes the GROW digital library unique, however, are the 5 other steps surrounding the interactive activity, which provide a context and clear educational objectives and outcomes. This includes an introduction before the activity, exercises after the activity to reinforce what students have learned, a summary that states the educational outcomes, an assessment of the student learning (challenge) and links to additional educational material. The learning units can be utilized stand-alone or, as a more likely scenario, as part of a collection of learning units completed in a particular sequence, called a "module". For example, Figure 3 shows three learning units (rocks and minerals, strength of rock, and build a tunnel) taken together to teach students how to design a tunnel in rock.

Figure 3. Example of a "Module", which is a collection of learning units with a clear learning outcome. This module demonstrates how 3 learning units can be completed in sequence to teach students how to design a tunnel in rock.

3.0 The Geotechnical, Rock, and Water Collections

This section of the paper gives specific details on the collections in the GROW digital library in the three initial target areas: geotechnical engineering, rock engineering, and water and its use.

3.1 The rock engineering collection

Dr. Kemeny is in charge of the targeted collection on rock engineering. The field of rock engineering is broken up into 6 topics: prerequisite science, rock engineering fundamentals, virtual lab, rock engineering modeling and design, virtual field trip, and research. This is shown in column 1 of the matrix in Table 1.

Topics	Subtopics	Community	K-12	Undergrad	Graduate	Professional
Prerequisite science	Math, Statics, Geology, Strength of mater, Statistics, Computer science	x	x	x	x	x
Rock engineering fundamentals	Intact rock, Discontinuities, Rock mass, In-situ stress, Induced stresses	x	x	x	x	x
Virtual lab	Uniaxial, Triaxial, Point load, Brazilian, Direct shear, P and S wave	x	x	x	x	x
Design and modeling	Slopes, Foundations, Underground, Computer models	x	x	x	x	x
Virtual field trip	Rock mass characterization, Monitoring	x	x	x	x	x
Research	Coupled processes, Imaging techniques, Modeling, Excavation, Slops, Fractures, Nuclear waste, etc.	x	x	x	x	x

Table 1. Matrix showing modules that are being developed for different topics and audience groups in the area of rock engineering.

The major subtopics within each topic are also shown. For each of these topics the digital library will contain collections that cater to the 5 audience groups: community, K-12, undergraduate, graduate, and professional. This is shown in the horizontal axis of the matrix in Table 1. In all there are 40 topics where digital information will be provided. As an example, consider laboratory testing. For this subtopic the undergraduate, graduate, and professional boxes are virtually identical and will contain 1) digital video of rock testing procedures, 2) a rock testing simulator to provide realistic and unique rock testing data (like the one shown in Figure 2), 3) spreadsheets to process the data, 4) report formats for the reporting of the results, and 5) links to the course material to provide the relevance of the results. However, for the K-12 and community boxes, repackaging of the material will take place. For these two audiences, the focus will be on why testing is needed, the rock breaking simulator to allow students to test their own rocks, and information about where the results would be used in engineering design. An example from the video demonstrating the point load test is shown in Figure 4.

Figure 4. Procedure for a point load test. a) sample preparation, b) testing

Dr. Kemeny is drawing on a number of sources in building the rock engineering collection. First of all, Dr. Kemeny is utilizing some of his own work [1,4]. Secondly, Dr. Kemeny is drawing on active individuals and organizations in the rock engineering community. One of the most important organizations is ARMA, the American Rock Mechanics Association [5]. This organization reaches out to the various industries, academic disciplines, government agencies, and international organizations involved in rock engineering, and also hosts an annual rock mechanics symposium. We are starting to work closely with ARMA in building and promoting interest in the rock engineering digital library. The rock engineering digital library will be open to all individuals to contribute information. In the spirit of the proposed work, these individuals should be interested in working with us to repackage the material to all of the 5 targeted audience groups.

3.2 The geotechnical engineering collection

Dr. Budhu, the project director, is responsible for the targeted collection on Geotechnical Engineering. The major topics for geotechnical engineering are: fundamentals of geotechnical engineering, virtual geotechnical lab, virtual site investigation, foundation design, numerical modeling, and virtual construction of foundation. Each of these have subtopics. For example, the subtopics for the virtual geotechnical lab are shown in Table 2. As an example, the interactive water content virtual lab is shown in Figure 5.

Dr. Budhu is drawing on a number of sources in building the geotechnical engineering collection. First of all, Dr. Budhu is utilizing some of his own work [7]. Secondly, Dr. Budhu is drawing on active individuals and organizations in the geotechnical engineering community.

Topic	Subtopic	Community	K-12	Under-graduate	Graduate/ Professional
Virtual Geotechnical Laboratory	- Water Content	X	X	X	
	- Grain size	X	X	X	
	- Index tests			X	
	- Consolidation			X	X
	- Direct shear			X	X
	- Triaxial			X	X
	- Simple shear			X	X
	- True triaxial				X
	- Hollow cylinder				X
	- Residual shear				X

Table 2: Matrix of the virtual geotechnical laboratory module

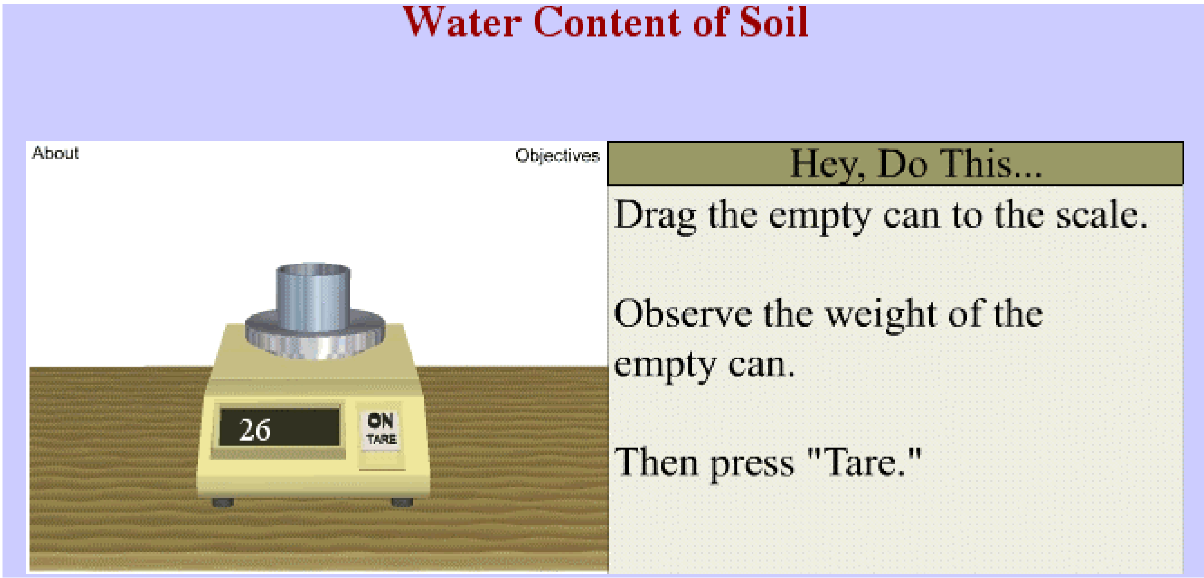

Figure 5. A screen shot from the water content virtual lab

3.3 The water and its use collection
Dr. Rasmussen is in charge of the targeted collection on water and its use. The water collection will house information on and offer links to water-related material that is suited for each of the target audience types to understand and use. A list of initial topics that we are now considering include: Water properties - surface tension, viscosity, density, pressure, thermal properties, state changes; Supply - aquifer, watershed, dams, river, CAP; Water Quality - testing, goals, cleanup,; Storage-water tanks, surface tanks, ponds, dams; Distribution - pipes, static/dynamic pressure, canals; Irrigation - pipe/ sprinkler, furrow, basin, strip, drip/ bubbler; Wastewater - sewer, septic tank, cleanup/ release; Evaporation/ET - vegetation, crops, swimming pool, lakes, suppression; Recharge - basins, river, watershed; Cooling - evaporative coolers; Aquifer- geologic material, water table, specific yield, subsurface flow, contamination; Wells - city, home, farm; Pumps - submersible, home, field; Infiltration - rate, soiltype, moisture content; Precipitation - rain, snow, measurement, RADAR; Watersheds - water yield, hydrologic cycle, water harvesting, health, water ownership; Dangers - floods, flooded washes, chemicals, organisms, drought; Prediction /analysis - precipitation, streamflow, water needs, critical supply.

4.0 The GROW Digital Library Infrastructure

This section provides information about the GROW digital library infrastructure. At the present time we are in the process of designing and prototyping the system architecture as described below. At the end of the prototype phase we will have a better understanding of how all the pieces are going to fit together.

The system architecture in the GROW digital library provides for the ability to store, maintain, access, identify, and use the content of the three collections, as shown in Figure 6. It contains 3 layers: a storage layer, a logic layer, and a portal layer. The first layer, storage, provides the actual content (learning modules, articles, media, etc.). On top of the storage layer sits the logic layer. This logic section provides the necessary information and metadata to discover, identify, and access the content in the system. On top of the logic layer rests the portal. The portal provides customized access to content, and allows the user to search and find relevant content and tools.

Consistent among all of the system layers is the use of open standards. Using open standards, such as XML, XSL, Dublin Core, OAI, etc. provides better and easier interoperability with a variety of content, and with other educational systems. Additionally, as appropriate, the software will be open source – that is, we will make the code freely available for others to implement, use, customize, and improve. By using a combination of open standards and open source software, we allow participation from both content and system adopters and provide a greater ability for others to implement and understand.

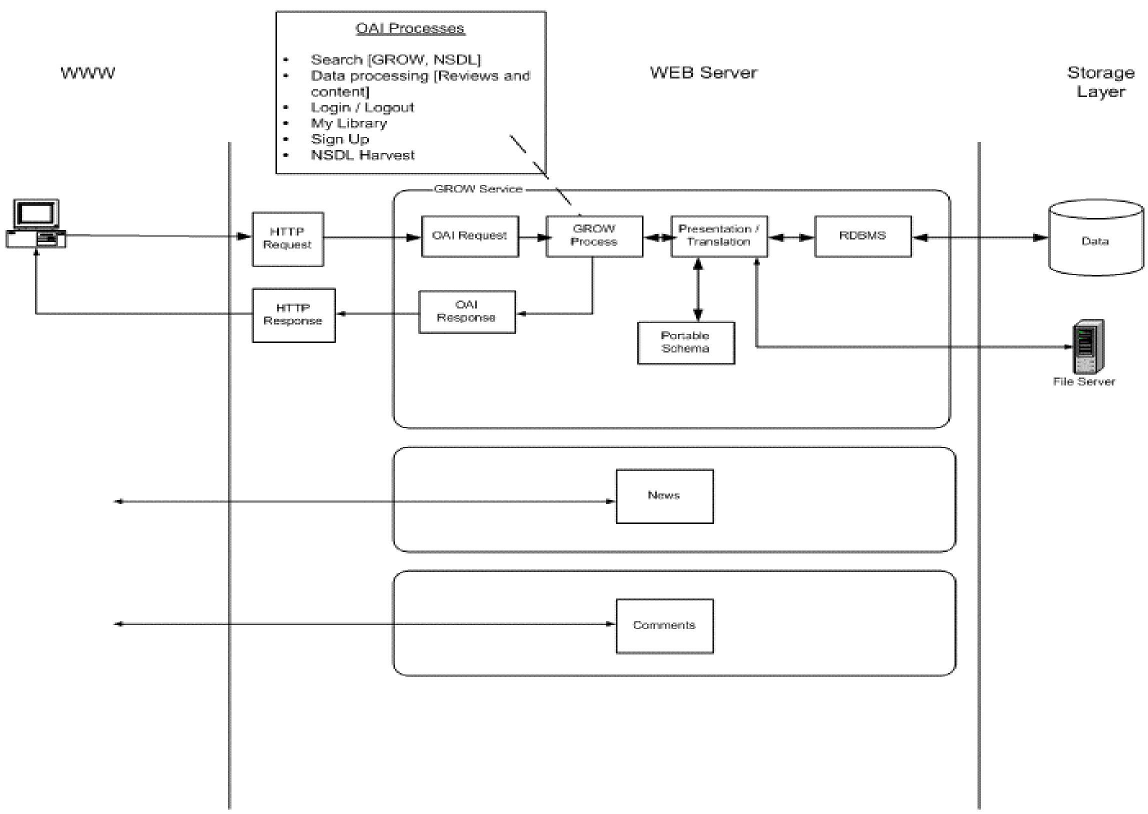

Figure 6. The GROW digital library infrastructure

The storage layer provides room for the content of the proposed project. The storage layer will be split into two areas, the database and the file server. The database, which will run on a MYSQL instance, will contain the metadata about the content. Along with the content metadata the database will store dropdown data that will be used on the web page, user information and content reviews. The database schema allows for multiple entries of certain metadata fields and also allows content to be linked. The metadata in the database will be retrieved using SQL and OAI protocols. The actual web page text, flash movies, audio, movies, images will be stored on a file server.

The logic layer, or glue, that will take requests from the web page and execute them or take a response from the storage layer and format it before returning a response to the webpage. This

Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition

layer will contain all the processing logic of the site, it will perform searches and return results, take metadata content and write it to the database, perform a login/logout of a user or respond to a NSDL harvest of the GROW metadata. The logic layer will be coded in Java and will possible use XML and XSLT. We plan to use Apache as a web sever with Tomcat running on it. Tomcat is a servlet container and will be used to house our java servlets and JSPs.

The metadata schema will be a combination of Extended Dublin Core records and records that will be specific for the GROW website. Each learning module or singular piece of content will be provided a metadata record. This metadata record will contain descriptive information that will allow a user to search for and determine if a piece of content is relevant to their needs. It will also contain information that relates it to other content within the system, as well as information on rights and copyright, and other administrative information.

The portal will be the public face of the project, and will provide access and organization to content for users [3]. It will be web-based and information will be organized by topic to insure the easy discovery of appropriate resources. Users will be able to evaluate resources through the portal by providing user feedback and comments on individual pieces or modules of content. The portal provides the ability to customize the delivery of content to users, by allowing the option for user accounts and logons.

5.0 Conclusions

The GROW digital library for Civil Engineering is being developed at the University of Arizona[3]. The initial focus of the digital library is on collections in three targeted areas: geotechnical engineering, rock engineering, and water and its use. An interdisciplinary team has been assembled that brings together faculty and staff from the College of Engineering, the University Library, the School of Information Resources and Library Science, the campus computer center, and the campus teaching center. There are several unique aspects to this digital library. First of all, the library will address specific learning and content needs for a number of different audience groups, including K-12, higher education, professionals and the community at large. Secondly, the collections will utilize modern multimedia techniques to promote active online learning. This includes interactive learning modules rich in animation, video, sound and images as well as an interactive questioning environment. Thirdly, the GROW digital library collections will focus on “learning units” that are self-contained learning lessons and provide clear educational objectives and outcomes. As part of the digital library, a host portal is being developed that will provide easy access to the collections in the three target areas and to allow for the growth of the collection in other areas of civil engineering. As part of the architecture for the library, a number of different types of reviews of submitted material will be possible, including academic reviews for quality control and user reviews. The educational value of the submitted material and of the library as a whole will also be assessed through an advisory panel consisting of teachers, students, professionals and other members.

Bibliography
1. Kemeny, J. and B. Zeitler. 2001. "An Online Geomechanics Course with a Virtual Rock Lab", 2001, Proceedings of the American Society for Engineering Education Annual Conference & Exposition, Albuquerque, NM, Paper 752, American Society for Engineering Education.
2. Kemeny, J. and B. Zeitler. 2001. "An approach to distance-learning courses based on streaming audio and vector graphics", 2001, Computers and Geosciences, 27:1119-1121.
3. URL: www.grow.arizona.edu
4. Kemeny, J., Poulton, M. & Zeitler, B., NATS 101: A Geo-engineering general education course with synchronous web and classroom delivery. *Proceedings of the ASEE Pacific Southwest Section Spring Conference*, University of Arizona (2000).
5. URL: http://www.armarocks.org
6. Poulton, M & Kemeny, J. A model for integrating technical preceptors in the classroom. In J.Miller, J. Groccia, M Miller (eds), *Student Assisted Teaching: A Guide to Faculty Student Teamwork*, Anker Publishing, Bolton, MA. (2001).
7. Budhu, M. 1999. Soil Mechanics and Foundations (textbook and CDROM), John Wiley & Sons, ISBN: 0-471-25231-X.

JOHN KEMENY
John Kemeny is an Associate Professor of Mining and Geological Engineering at the University of Arizona in Tucson. Dr. Kemeny received his Ph.D. from the University of California at Berkeley in 1986. In the past 5 years Dr. Kemeny has been actively involved in instructional technology. In addition, Dr. Kemeny teaches undergraduate and graduate courses in engineering and general education, conducts research on the mechanics of fractures in rocks, and has started a company that develops image-processing software for the mining industry.

ELENA BERMAN
Assessment and Faculty Development Specialist, University of Arizona. Dr. Berman has extensive experience in faculty development and assessing teaching effectiveness. She has worked with both the College of Engineering and Mines and the College of Social and Behavioral Science on several projects involving the improvement of teaching and student outcomes. She has extensive experience in the educational and evaluation needs of general education and technology programs.

PAUL BRACKE
Systems Librarian at University of Arizona Library. Mr. Bracke is involved in the development of systems-architecture models to enable more effective planning of library automation at the University of Arizona and is a consultant with the Academic Technology Center at the University of Texas Medical Branch at Galveston on educational applications of web technology.

WAYNE BRENT
Manager, Center for Computing and Information Technologies, instructional applications support. Mr. Brent manages the installation, maintenance and support of various web tools for teaching and learning including: UACBT, WebCT, Caucus Conferencing, Old Pueblo MOO, POLIS, general Instructional Computing web space, FrontPage server, Oracle Instructional server. He also manages and directs instructional applications, modifications, development and integration. He leads various projects and campus initiatives including Ucluster, Portals, Authentication & Authorization, Communications tool replacement, Faculty Development, Library, Integrated Learning Center, Innovations in Learning/Technology/Assessment, Southwest Project and actively participates in local, regional and national forums related to education, technologies and assessment.

MUNIRAM BUDHU
Professor of Civil Engineering and Engineering Mechanics. He has over 20 years of teaching and research experience in several disciplines of civil engineering. He is an active professional engineer and have been involved in several civil engineering projects involving geotechnical engineering, drainage and irrigation, erosion, earthquake engineering, infrastructure systems, environmental engineering and building design. Dr. Budhu recently published (Publisher: John Wiley & Sons, 2000) a textbook/CD titled " Soil Mechanics and Foundations" that has been

adopted at many Universities in the US and abroad. One of the unique features of this book is the integration of a wide selection of digital media and tools – interactive animation, digital video, electronic quizzes, interactive problem solving, electronic notebook, graphics, text and sound – on a web compatible CD to enhance learning.

ANITA COLEMAN
Assistant Professor in the School of Information Resources and Library Science (PI).
Dr. Coleman has been involved in the design and management of user-centered information systems and services in academic libraries for the last 12 years. Most recently she was a Visiting Researcher on the Alexandria Digital Library Earth Prototype, NSF-funded DLI-2 and the National Science Digital Library projects at the University of California at Santa Barbara. These integrated research projects sought to demonstrate a geo-referenced digital library that can be used for undergraduate teaching and learning. Working with ADEPT and NSDL team members at UCSB, researchers at UCLA, SDSC (San Diego), NASA, and DLESE (Colorado),

RONAN DEMPSEY
Dempsey is involved in the design, development and roll out of the GROW project. His responsibilities include managing the creation of content (Flash and HTML), the design of the website, database and architecture with the help of Mr. Brent, Mr.Bracke, Mr. Frumkin and Mr. Przybylski. He and Mr Przybylski will be developing the website. In the past he has worked as a consultant designing and building website for different companies.

JEREMY FRUMKIN
Metadata Librarian for the University of Arizona Library. Mr. Frumkin's current work involves the development of systems and tools that work with metadata, primarily in the areas of information access and identification. He is also involved in developing customized systems (i.e. portals), and is Co-PI for NSF grant DBI-0078294, relating to a customized interface and display of phylogenetic information called the Tree of Life (http://www.tolweb.org). Mr. Frumkin is also the chair of the Open Source Systems IG of the American Library Association, and is a member of ALA's task force on electronic books and media.

MALIACA OXNAM
Engineering Librarian for the areas of Civil Engineering, Hydraulic Engineering, Optical Engineering, Systems & Industrial Engineering and Materials Science at the University of Arizona. Ms. Strom is currently in charge of the Customizable System Planning Team at the UA Library, which aims to develop a customized interface for users increasing their accuracy and efficiency in finding appropriate information resources. Before coming to the University of Arizona, Maliaca served as the Information Technology Specialist for the University of Southern California's Science Center where she coordinated technology development for the science libraries. Contributions included strategic planning and development efforts for portions of the USC Electronic Resource Database (http://www.usc.edu/isd/elecresources/).

LEO PRZYBYLSKI
Programmer/Analyst, Leo is working with development of data collection processes, data storage interfaces, and data search/discovery applications. He has experience in building data warehouses and data collection frameworks.

WILLIAM RASMUSSEN
Associate Professor in Soil and Water. He brings to the project a broad range of experiences, skills, and knowledge in water and its use and in multimedia. He was trained in physics, geophysics, hydrology, and watershed management. He has taught courses in Water and Its Uses, Watershed Simulation, Environmental Simulation, Watershed Management, Applied Hydrology, Remote Sensing, Geographic Information Systems, and Wildland Geophysics. He has also developed a large system of Ecosystem Component Simulation Models for the USDA Forest Service and for various land and resource management agencies. He has developed computer models for use in predicting floods and the potential impacts from them. He has also developed data analysis packages for use with streamflow, precipitation, and wind data sets. He has developed and currently teaches a broad introductory science course as part of the new core science program at the university. He is also involved in efforts to develop mathematics across the curriculum and writing across the curriculum.