ADDING TRAINING FEATURES TO AN INFORMATION WEB SITE

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Abstract

Web-based training (WBT) is an ideal vehicle for delivering training to individuals anywhere in the world at any time. Advances in computer network technology and improvements in bandwidth will render the WBT option increasingly interesting over the next decades. However, new technologies impact educational methods slowly. For example, the introduction of the overhead projector has yet to replace the use of chalk in the classroom, a very small change indeed. This paper presents a conservative approach to the introduction of WBT in the classroom by building-up WBT features into an existing information Web site.

Introduction

Web-based training (WBT) is an innovative approach to distance learning in which computer-based training (CBT) is transformed by the technologies and methodologies of the World Wide Web, the Internet, and intranets. Web-based training can present live content, as fresh as the moment and modified at will, in a structure allowing self-directed, self-paced instruction in any topic. WBT is media-rich training fully capable of evaluation, adaptation, and remediation, all independent of computer platform. The current focus of WBT development is on learning how to use the available tools and organize content into well-crafted teaching systems.

Potential advantages of the Web based training approach over conventional course offerings include access to a larger target population and optimization of instructors' availability. However, experience has shown that, despite advances in software applications, an enormous investment in professional time is required to produce credible course material. The advantages and disadvantages of computer based training (CBT) and more conventional education techniques are summarized in Table 1 [1]. The work presented in the present paper illustrates how it is possible to reengineer an existing information Web site by adding features to support WBT. Such an incremental approach to WBT development will hopefully help avoid many of the pitfalls facing the introduction of a new technology in the classroom while providing the means to test some concepts before the creation of full-scale training packages.

Designing a Computer Based Training Course

To organize materials for on-line teaching and training, it is useful to cast discussions about what to teach on-line into a standardized pedagogical framework. Current Web-based materials are frequently only presentations of information that do not fit into an intellectual schema for training. If we are to create materials on-line, the creation and presentation of these materials should be driven from a mental model of what engineering students should learn. What should engineering students learn? This is not a trivial question [2]. Engineers do need to learn on their own, deal with unexpected situations and solve problems.

Following the example provided by Bourne, the types of things that engineering students should learn have been classified into two well-known taxonomies in education [2]. Barrett's taxonomy proposes that learning should be divided into four categories: literal recognition (recall), inferential comprehension, evaluation, and appreciation [3]. Merrill's taxonomy uses a performance-context matrix that includes the actions of remember, use, or find(create) [4]. The content is classified as fact, concept (classification), procedure or principle. The taxonomies appear to be useful for classifying learning outcomes in engineering and in selecting the technology required for on-line implementation. Table 2 presents some typical learning outcomes that may serve as a basis for classification of how we should structure engineering learning scenarios (adapted from [2]). Examples are given in the right hand column of particular engineering problems in the area of corrosion engineering.

One of the most significant capabilities that can be supplied to users is interaction. Presentation of text and graphic materials in hypertext form is indeed useful; however, Web-based materials are significantly more interesting when they are interactive. For example, a common technique is to add forms to hypertext markup language (HTML) documents so that the user can interact with the Web page. In an on-line classroom setting, this type of capability can be very useful for creating surveys, tests, and shared materials. Animation, tutorial systems, and access to bulletin boards, provide additional capabilities. With a Web browser, it is very simple to embed access to file transfer protocol (FTP). Thus, if there are files that students need to download, this capability can be embedded directly in the HTML document. The following list displays the types of desired education outcomes and how these outcomes can be facilitated by different components of the training model [2]:

1. Easy access to knowledge: The Web greatly facilitates access to all kinds of knowledge stored on FTP sites, in libraries, and on HTTP servers that can greatly facilitate an engineering student's search for information.

2. Learning to work in a team: Working in teams has become the norm in the engineering industry. Further, teams are often constituted from individuals who are not in the same location. With excellent network capabilities, teams of individuals with specific expertise can be easily brought together electronically to rapidly accomplish a task. In engineering education, we need to emulate this environment so that students can have preparatory experiences that will mimic the real engineering environments that they will encounter after graduation.

3. Design discussions: Design can be facilitated using on-line discussions among teams of student designers at different institutions.

4. Immediate feedback: Providing immediate feedback to instructors and students alike is an essential component of the training model. The common gateway interface (CGI) of HTTP servers permits writing programs that can access and manipulate data supplied from Web clients.

5. Continual monitoring and self-evaluation: CGI permits doing such things as monitoring which students access materials, determining when and where students use materials, accessing the state of knowledge of a class continuously, providing homework grading, feedback and on-line testing.

6. Laboratory experiences: The lecture and laboratory can be more easily combined using on-line methods. Current courses that are on-line provide lecture materials and interactive questioning. Laboratories can be provided either via simulation programs or via demonstration. Combining lectures and laboratories can be quite useful for on-line education.

Reengineering an Existing Web Site

There are quite a few Web sites containing elements of corrosion information. A search of the generic term corrosion would typically find upwards of 400,000 Web pages with variable references to the subject. The following sections will discuss various aspects related to the creation, development, and operation of the Corrosion Doctors Web site. From its launching in mid August 1999, the site has reached an interesting level of Web traffic in its first eighteen months of existence, with positive indicators that the site is actually fulfilling its initial goal of bridging large distances across many disciplines.

Early Days (1997-1998)

Two information modules and one Aircraft Corrosion Newsletter had been developed in the early part of 1997, following the suggestion made by military personnel at one Canadian Forces Base. The main goal of these Web pages was to improve the communication of complex data and concepts between distant locations. The pages were created using a very efficient tool, Frontpage 97, requiring a minimum of programming skills. However, while these pages were developed in a relatively straightforward manner, they had to be transferred to a UNIX based Web server by a different team, with a few levels of bureaucratic annoyances. In practice this met that the pages turnover was very slow and absolutely limited to HTML code.

The Corrosion Doctors Site

The interest and need to interface to a largely distributed community were reexamined in a study carried out by an external advisor in the first part of 1999. One obvious conclusion of the study was to seek a Web service adapted to the development tools chosen and free of local politics. The reengineered site was launched in mid August 1999 as the ***Corrosion Doctors***. It was decided, early in the existence of the site, to build it on feedback and collaborations from the broadest community possible. Most of the first months of the Web site development were spent learning the rudiments of information for Web delivery while conducting surveys designed to reveal specific aspects of the corrosion engineering profession.

The Surveys

Six surveys were conducted by inviting the active participants of two well known Internet corrosion discussion groups [5;6], totaling approximately twelve hundred active members, to reach a specific page of the site and answer a set of both short and specific questions related to one of the following themes:

- 1st Survey: Human Errors in Corrosion, 50 participants
- 2nd Survey: Educating the Corrosion Engineers, 60 participants
- 3rd Survey: Information Sources, 52 participants
- 4th Survey: Facing Management, 42 participants
- 5th Survey: Working with Others, 31 participants
- 6th Survey: Computer Based Training, 94 participants

The first five surveys were based on a landmark paper by Francis LaQue originally published in 1978 and reprinted since then [7]. Typically, list members were notified of a survey or of its displayed results. As can be seen in the previous list, some of these surveys were more popular than others. Figure 1 illustrates a section of the dynamic HTML page for the survey designed to reveal the importance of different information sources used by corrosion engineers and Figures 2 and 3 show respectively the breakdown of answers to the question “What is the most dependable information source you depend upon to carry your work?” and to the question “What is the least dependable information source you depend upon to carry your work?” The information explaining the surveys, the surveys themselves as well as their results have been edited and processed into pages of the site.

Information Modules

The Corrosion Doctors site presently contains corrosion information from a multitude of sources. The backbone of the information assembled during the first year of operation was constructed in specific themes gathered in information modules. One of the main advantages of Web publishing is the flexibility permitted by inter-linkages. With some careful design considerations, it is possible to continuously and seamlessly develop sections of a Web site without the users or visitors of the site being inconvenienced or annoyed by these changes. The approach chosen for this maximum flexibility was to use frames for each module and an open architecture for the main pages of the site. Each module would thus have its own table of contents supporting an internal navigation scheme and a banner to identify its location in hyperspace. The Corrosion Doctors Web site presently contains thirty-nine information modules divided in the following categories:

- Corrosion Basics (17 Modules)
- Corrosion Prevention and Control (12 Modules)
- Corrosion Testing (4 Modules)
- Education vs Corrosion (2 Modules)
- Electrochemical Power Sources (4 Modules)

News Bulletins

The News Bulletins were created to accelerate the diffusion of the site activities. People are busy and searching the Web for corrosion information is neither their main preoccupation nor even an accepted information gathering method. If one believes the results of the survey on the Information Sources used by modern corrosion engineers, the Web would be the least credible source of information one would consult (Figure 3). It is generally felt, at least in the corrosion community that is active in the Internet discussion groups that the quality of technical information is simply not there yet. Such a sentiment cannot be generalized to other professions and other disciplines such as environmental science and other scientific areas since excellent and informative sites have reached the top of visibility charts, achieving to attract record numbers of visitors.

In order to build up the interest for the information displayed on the site, it was decided to create the News Bulletins for direct Internet distribution. The first issue was sent to approximately three hundred recipients in March 2000. Subsequent Bulletins were sent at regular intervals to a growing list of recipients. The impact of these News Bulletins on site visits was immediate.

Site Index

One feature that was immediately accepted by both human and machine visitors was the site Index. The Index was created to overcome the partitioning caused by the use of frames initially for the construction of the information modules and subsequently for the pages of the Corrosion Doctors Journal. Navigating through the Web site had become increasingly complex as the number of information modules and the number of associated pages had grown into a real maze. The site Index lists, for each letter of the alphabet, hypertext references to most pages of the site that, in turn, have a return link to the Index.

The main difficulty was to decide how each page would be referenced for the site Index as well as for visiting spiders and crawlers. However, the effort was not done in vain since many of the keywords used in the indexing process have now reached the highest level of citation with most of the popular search engines. An additional feature was added for the human visitors, allowing them to search the site using their own words and Boolean logic to find citations directly related to their queries (Figure 4).

The Corrosion Doctors' Journal

Six papers have been published in Volume 2000 of the Corrosion Doctors' Journal. As with the information Modules, special care was given to the presentation of these papers in a fashion that permitted full integration of the Journal content into the site with an almost infinite level of possibilities of interlinks and hyper-referencing. A different navigational arrow has been used in the Journal pages to provide internal linkages while giving a sense of orientation to visitors coming to a specific page of the site from external referrals. There is presently no ambition to promote the Corrosion Doctors Journal out of the site context and compete with existing publications. The feature is experimental and wants to prove that high level corrosion information can be distributed through the Web. It is also a simple method for absorbing complete documents without the need to condense and digest the information unnecessarily.

Building up the Training Center

After a little more than one year of development, the site contained close to one thousand pages of diverse and tested Web material. Two new features were then created to add depth to the site content, the Web Journal mentioned in the previous section and a Training Center. This Training Center was considered to be a prudent approach for testing some concepts of WBT before developing full scale training packages. These experiments were deemed necessary since development guidelines, market analyses, or accreditation requirements are greatly missing in this new promising field of communication and information processing.

Educators' list

A survey was designed to help define who could be interested to use the Corrosion Doctors site as a support medium for training in corrosion science and engineering. Filling up this survey was the first step in joining the Corrosion Doctors Educators' list. This survey, as with all the surveys carried so far on the site, was constructed in a manner that could be answered in a few mouse clicks. There was also room for more elaborate comments. The survey participants were asked to provide contact information and some details on their teaching experience and actual teaching involvement. Following this preamble, the participants were asked to select the most useful topics amongst a list of twenty-four titles corresponding to Modules of the site. Twenty-seven participants have so far cast their ballots and the results obtained are summarized in Table 3.

Refocusing Web Development Efforts

One important exercise in reengineering the site towards a new role was to analyze its features in terms of development effort as a function of the dynamic potential of these features and interest shown by visitor frequency (Figure 5). The dynamic potential axis in this figure represents the easiness to change, add, or subtract from each page or feature. While both the Journal and the Training Center were designed to provide depth to the site, reengineering the site towards training made much more sense in terms of efficiently developing a Web site with limited resources and funding support. Following this analysis, it was decided to gradually dismantle the Journal and all its associated features and focus on furthering the Training Center.

Dynamic Problems

Most learning outcomes presented in Table 2, with the exception of the Literal (Barrett) or Remember (Merrill) outcomes, can be advantageously supported in a Web format by numerical questions.

Individualized Problems

Typical engineering tasks require that specific goals be reached using a diversity of mathematical tools varying with contexts and situations. The main virtue of regular assignments, when teaching an engineering topic, is to keep the students focused on reasons and methods to accomplish specific tasks. Teaching corrosion engineering means going through detours in various fields that do not necessarily seem to be related, at least to an average student. It is possible to compensate for the absence of direct supervision in Web training by individualizing the data sets used required problems (Figure 6).

Situational Problems

The breadth of information presently on the site can also be used to build questions on specific themes. The problems presented in this second type of exercises are much more complex and typically preceded by a detailed introduction leading to specific questions. In this example, the students would be presented with an established method to passivate new steel structures exposed to a marine environment. Corrosion engineers generally recognize the value of calcareous deposits in the effective and efficient operation of marine cathodic protection systems.

Background Information. The calcareous films are known to form on cathodic metal surfaces in seawater, thereby enhancing oxygen concentration polarization and reducing the current density needed to maintain a prescribed cathodic potential. While this practice is quite straightforward and commonly used to commission new steel tanks or vessels for seawater applications, the detailed chemistry can be quite complex. The principle of forcing calcareous deposits by cranking up the cathodic current to produce a very alkaline interface on a steel surface is explained by invoking the multiple equilibrium controlling carbonate species in seawater and the mechanism of blocking an electrode by the creation of a diffuse layer. The detailed chemistry involved in this process is displayed on the Web site [8] and the questions that can be asked to a student follow.

Questions

1. Given that the corrosion rate of unprotected steel is **1.1 mm y^{-1}**, estimate the total corrosion current for one pillar.
2. Given that the zinc anodes can provide a sacrificial current corresponding to a corrosion rate of zinc of **7 mm y^{-1}**, evaluate the number of anodes that would be required to reduce the corrosion of steel by a factor of ten. Assume that the total corrosion current calculated in 1. remains the same to balance a constant cathodic process, the reduction of oxygen.
3. In order to reduce the consumption of anodes over time you would like force the precipitation of calcareous deposits onto your steel surface because you know that, by doing so, you can cut down

the corrosion of steel a hundred fold. Knowing that the level of Ca^{2+} in seawater is **0.01 m** and that the diffuse layer is approximately **5 mm** thick:

a) Calculate the current density that would be required to force the precipitation of insoluble aragonite onto the steel close to the water line;

b) How many sacrificial anodes per m^2 would be required to provide this initial protective current?

c) What would the impact on the current density requirements of attempting to deposit aragonite in an agitated sea ? Please be specific in your answer.

Answers. The answers to these questions are illustrated in Figure 7. As for the previous example, some of the variables can be changed to produce individualized problems for immediate feedback or automatic marking.

Summary

Advances in computer network technology and improvements in bandwidth will usher in capabilities for unlimited multimedia access. Web browsers that support 3-D virtual reality, animation, interactions, chat and conferencing, and real-time audio and video will offer unparalleled training opportunities. With the tools at hand today, it is possible to craft highly effective WBT to meet the training needs of a diverse population. As instructional designers and training analysts learn how to write and produce WBT, and as training vendors come to realize the overwhelming advantages of this delivery method, an explosion in training offerings available can be expected.

However, transitions to new technologies in education are usually very slow and progressive. The quantum leap offered by communication technologies presently available may take a few more years to transpire across real classrooms. Another handicap to a rapid change to WBT is the sheer effort required to develop decent course offerings. This paper has presented a middle ground approach in which an existing Web site was partly reengineered to test some training concepts. This work in reusability was perceived to be a small investment of efforts for a great return.

Figure Captions

Figure 1: The first two questions of a survey designed to reveal the importance of different information sources used by corrosion engineers.

Figure 2: Compilation of the results to the question “What is the most dependable information source you depend upon to carry your work?”

Figure 3: Compilation of the results to the question “What is the least dependable information source you depend upon to carry your work?”

Figure 4: Customized search facility supported on the Corrosion Doctors site.

Figure 5: Schematic representation of four types of features supported on the Corrosion Doctors site as a function of visitor frequency, number of pages per topic, and dynamic potential.

Figure 6: A simple corrosion problem with its fully developed solution and indicated changeable variables.

Figure 7: Sample solution to the situational problem on forming calcareous deposit on a newly laid steel structure in seawater.

References

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7) LaQue FL. What can management expect from a corrosion engineer? Materials Performance 1985; 25(8):82-84.

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Table 1 - The advantages and disadvantages of CBT when compared to conventional education techniques.

Advantages	***Disadvantages***
Potential for achieving higher student cognition	Lack of human interaction and engagement
Direct linkages to Internet resources	Lack of teamwork
Rapid updating of information and course materials	Low inspiration factor, especially when working in isolation
Efficient retrieval of specific information using electronic text processing	Limited verbal communication skills development
Wider choice of course offerings for students	Requirement for expensive hardware
Achieving special learning objectives through computer simulations (for example key technical concepts, role playing, decision making processes and their consequences)	Need for special computing and software skills, mainly on the part of the developers
Access to a large student and professional “market”	Production of CBT material is (extremely) time consuming and costly
Student interaction with course material	Non-uniformity of hardware affecting product quality
Higher student attention levels by stimulating multimedia presentations	Need of support staff
Tracking user interaction with the course material	
Optimization of a steadily shrinking expert instructor pool	
Freedom to follow individual pace and learning styles for students	

Table 2 - Examples of typical learning outcomes.

Typical Engineering Knowledge	**Barrett**	**Merrill**	**Sample Problems**
What is . . . (identification)	Literal	Remember fact	What are the units of corrosion penetration rates? Relate these to Faraday's law
Recall characteristics	Literal	Remember concept	State the characteristics of each type of corrosion testing studied.
Describe a process	Literal	Remember process	Describe how the linear polarization method can yield corrosion rates.
How to do something	Literal	Remember procedure	List the procedure to draw an Evans' diagram.
Set up a problem using guidelines	Literal	Remember principle	State the guidelines to design an anodic protection system.
Recognize types of corrosion inhibitors	Inferential	Use a concept (classify things into categories)	Given these five corrosion inhibitors, identify which are passivators.
What will happen if?	Inferential	Use principle	What will happen if the pH of a steel vessel was to drop below 6.2 from 10.2?
Apply a learned pattern or sequence	Appreciation	Use procedure	Using the information in the cathodic protection module, calculate the number of sacrificial anodes that would be required to form a calcareous deposit on a steel pile immersed in seawater.
Linkage between theory and practice	Appreciation	Use principles (laws and heuristics) to solve a problem	Use the Pourbaix diagram of Cr to determine the control current and potential for the anodic protection of a S43000 stainless steel vessel.
Linkage to real world complexity	Appreciation	Use principles	Using straight value depreciation, decide between two copper-nickel alloys for the design of a heat exchanger.
Creating specifications and implementing	Evaluation	Find principles	Evaluate the corrosion monitoring needs of this section of a chemical processing plant and design a cost effective strategy to generate reliable data.
Finding out (analyzing)	Evaluation	Find principles	Create a set of guidelines to determine the points of a plant susceptible to localized corrosion.

Table 3 – Results of the survey on using information modules in support of training.

Corrosion Basics	**Intereste d**	**% interest**
Atmospheric Corrosion	13	48
Causes and Forms of Corrosion	21	**78**
Hot Corrosion	9	33
Kinetics	16	**59**
Elements of Risk	12	44
Microbiologically Influenced Corrosion	11	41
Natural Waters	9	33
Reference Electrodes	12	44
Reinforced Concrete	5	19
Seawater	13	48
Soil Corrosion	6	22
Thermodynamics	16	**59**
Corrosion Prevention and Control		
Anodic Protection	9	33
Cathodic Protection	15	**56**
Corrosion Inhibitors	14	**52**
Corrosion Monitoring – Basics	15	**56**
Inspection	11	41
Life Prediction	14	**52**
Materials Selection	14	**52**
Protective Metallic Coatings	20	**74**
Protective Organic Coatings	13	48
Corrosion Testing		
Corrosion Testing – Basics	19	**70**
Electrochemical Test Methods	22	**81**
Testing for Pitting and Crevice Susceptibility	12	44

Portrait of a Corrosion Engineer

In his 1952 paper, F.L. LaQue stretched the importance of basic knowledge for performing good corrosion engineering and the requirements of reliable information sources. In this second survey we, the **Corrosion Doctors**, are trying to identify on which information sources you, noble visitor, depend for your daily work and where you see progress should be made.

Please answer the following questions simply stating your opinions by clicking on one of the options provided. The questionnaire looks longish, however the questions all state the same information sources with different degree of usefulness (you could be out here in six 'clicks' if you so wanted).

1. In your daily life as a corrosion specialist, what is the **most dependable** information source you depend upon to carry your work?

   ○ Books
   ○ Journals
   ○ Conferences & their associated activities and publications
   ○ Software systems (databases, CDs, etc.)
   ○ Own network of friends and contacts
   ○ Internet discussion groups such as UMIST, NACE and others
   ○ Internet sources others than above, e.g. Web sites
   ◉ Other

   [ ] write here only if you selected **other**

2. In your daily life as a corrosion specialist, what is the **second best most dependable** information source you depend upon to carry your work?

   ○ Books
   ○ Journals
   ○ Conferences & their associated activities and publications
   ○ Software systems (databases, CDs, etc.)
   ○ Own network of friends and contacts
   ○ Internet discussion groups such as UMIST, NACE and others
   ○ Internet sources others than above, e.g. Web sites
   ◉

   [ ] write here only if you selected **other**

Figure 1: The first two questions of a survey designed to reveal the importance of different information sources used by corrosion engineers.

Adding Training Features to an Information Web Site by P.R. Roberge

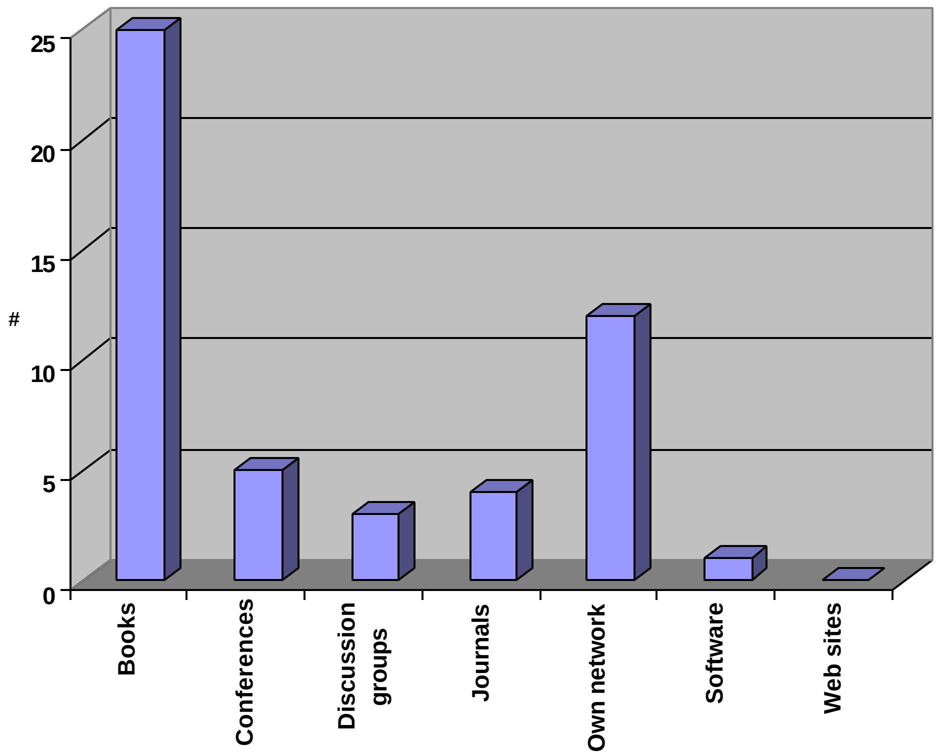

Figure 2: Compilation of the results to the question “What is the most dependable information source you depend upon to carry your work?”

Adding Training Features to an Information Web Site by P.R. Roberge

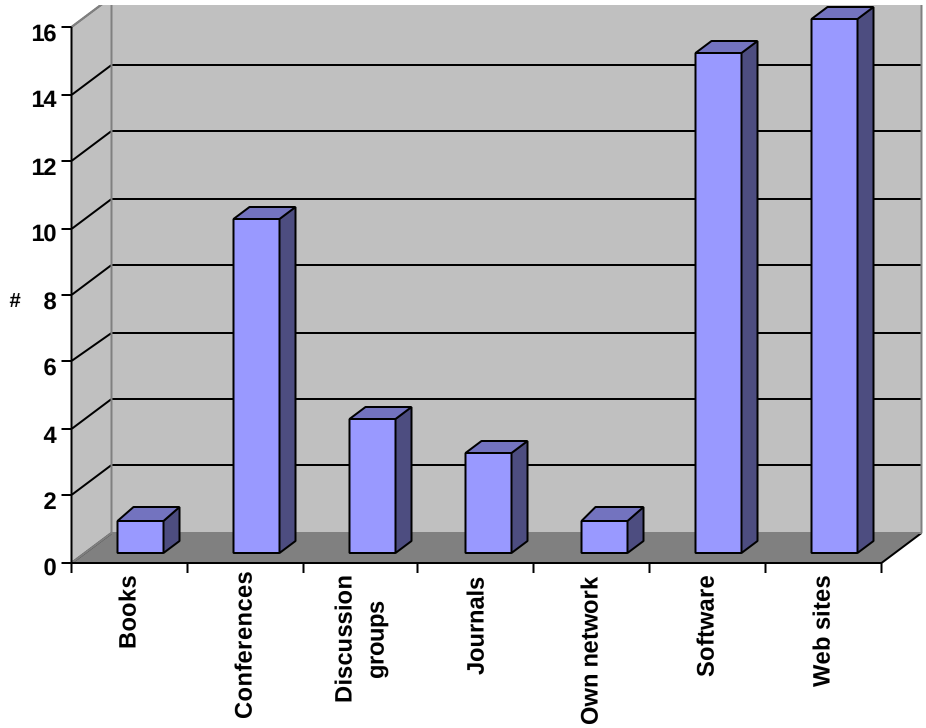

Figure 3: Compilation of the results to the question “What is the least dependable information source you depend upon to carry your work?”

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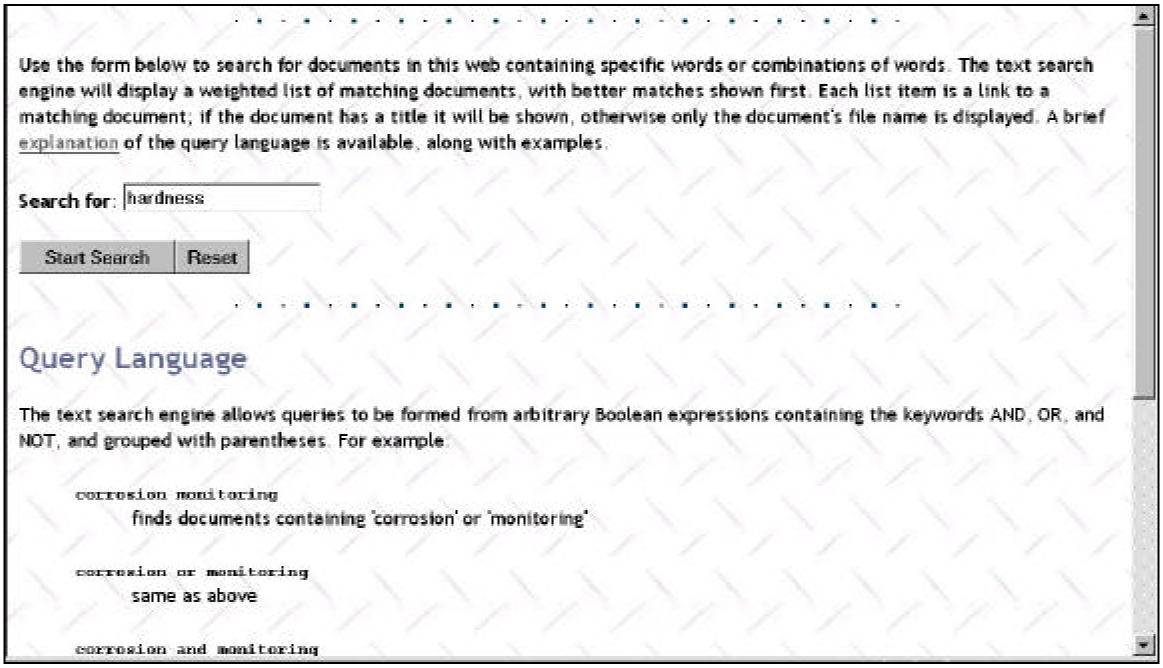
Use the form below to search for documents in this web containing specific words or combinations of words. The text search engine will display a weighted list of matching documents, with better matches shown first. Each list item is a link to a matching document; if the document has a title it will be shown, otherwise only the document's file name is displayed. A brief explanation of the query language is available, along with examples.

Search for: hardness

Start Search | Reset

Query Language

The text search engine allows queries to be formed from arbitrary Boolean expressions containing the keywords AND, OR, and NOT, and grouped with parentheses. For example:

corrosion monitoring
finds documents containing 'corrosion' or 'monitoring'

corrosion or monitoring
same as above

corrosion and monitoring

Figure 4: Customized search facility supported on the Corrosion Doctors site.

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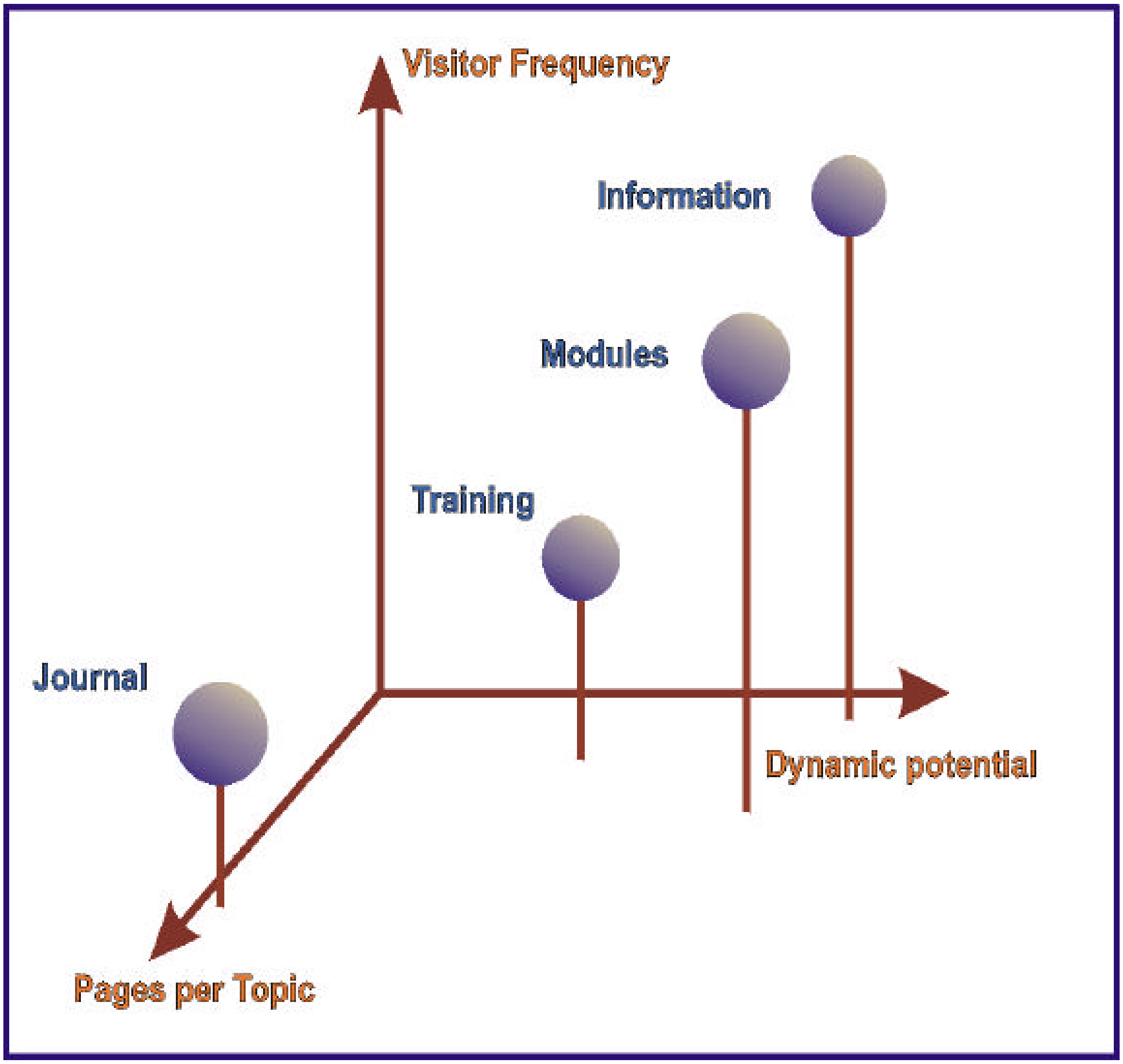

Figure 5: Schematic representation of four types of features supported on the Corrosion Doctors site as a function of visitor frequency, number of pages per topic, and dynamic potential.

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A useful corrosion reaction

Problem

The familiar D size MnO_2/Zinc Leclanche primary cell contains 32 grams of MnO_2. The discharge reaction at the positive electrode is:

$$MnO_2 + H^+ + e^- \rightarrow MnOOH$$

The Zn that oxidizes during discharge is supplied from the cell casing which may be taken to be a thin walled cylinder with a radius 4.5 cm that is 5 cm tall. How thick must the wall thickness be if the casing is not to perforate before the cell is "dead"? Provide for a 50% safety factor. The molar mass of Zn is 65.38 g mol^{-1}; the density is 7.14 g cm^{-3}.

What is the nominal charge this cell can store? Express the answer in ampere-hour (Ah), knowing that 1 Ah is equivalent to 1 A (C s^{-1}) x 3600 s h^{-1} or 3600 C.

Solution

Constants					
	F (C/mol(e)) =		96485		
Data					
MnO_2	MW (g mol^{-1})=		86.94	**Mass (g) =32**	
	n (e) = 1				
Zn	MW (g mol^{-1})=		65.38	density (g cm^{-3}) =	7.14
	n (e) = 2				
	height (cm) =		**4.5**	radius (cm) =	1.5
	safety factor (SF) =		1.5		
Calculations					
MnO_2	Moles:	mass/MW (mol) =		0.3681	
	No C:	mol x F X n (C) =		35513.23	
Zn	Moles:	C/n =		0.1840	
	mass:	moles x MW (g) =		12.03	
	volume:	mass/density (cm^3) =		1.69	
	surface:	h x r x 2 x pi (cm^2) =		42.41	
Answers					
a) Zinc thickness					
	thickness:	**vol/surf (cm) =**		0.0397	
		x SF =		**0.0596**	
b) Charge					
			C/3600 =	**9.865 Ah**	

Figure 6: A simple corrosion problem with its fully developed solution and indicated changeable variables.

1) Corrosion current

surface area of one pillar: diameter (d), length (l)

d = 1 l = 25

pi x d x l = **78.54** m^2

corrosion rate = **1.1** mm y^{-1}

corrosion current

1 mm y^{-1} = 0.0863 mA cm^{-2}

total = 74.56 A

2) Number of sacrificial anodes

surface of each anode length (l), thickness (t), width (w)

l = 100 t = 12 w = 12

face	1200
sides	2400
ends	288
total	3888 cm^2

valency (n),density (den),Molar mass (M)

conversion in current 1 mm y^{-1} = n x den x 0.306/M

CR Zn = 7 Mm y^{-1}

or 0.4674 mA cm^{-2}

per anode

1.8172 A

current to be produced efficiency = 90 %

67.1 A

number of anodes = 36.9

3 a) Limiting current at water line

lim I = n x F x D xC/delta

n = 2

F = 96485

D = 5.00E-05 cm^2 s^{-1}

delta = 5.00E-04 Cm

C = $(6.7 \times 10^{-7})/0.01$ = 6.70×10^{-5} mol kg^{-1}

or 6.70×10^{-8} mol cm^{-3}

lim I = 1.29×10^{-3} A cm^{-2}

or **1.29 mA cm^{-2}**

3 b) number of anodes

for 1 m^2 current = 12.93 A

requiring **7.11 anodes** since 1.8172 A per anode

3 c) Agitation effect

Agitation would force the limiting current to increase
and the number of anodes to increase.

Figure 7: Sample solution to the situational problem on forming calcareous deposit on a newly laid steel structure in seawater.