Framework for a Computer Based Corrosion Course

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Abstract

A framework for a computer based corrosion course has been developed, with a view to distance learning applications. Potential advantages of the computer based learning approach over a conventional course offering include access to a larger target population and optimization of the shrinking expert instructor pool. However, experience has shown that, despite advances in software applications, an enormous investment in professional time in planning and developing the course material is required. This computer based corrosion course is unique, in that emphasis has been placed on quantitative material, rather than on more descriptive subject matter often found in existing corrosion education products. The course was also designed to be fundamentally interactive in nature, with the use of situational case studies and assignments, in direct contrast to some approaches of re-creating books in hypertext format. Course modules have been created initially in paper based format, to place the scientific/technical course content on a sound footing. Selected case studies and assignments have subsequently been designed in electronic format to develop skills in applying the knowledge and understanding gained from the paper based course notes. Following detailed planning, additional work is underway to present further selected material in electronic format.

1. Introduction

Corrosion Science and Engineering (CSE) is an important element of chemical engineering education, at both the university student and practicing professional levels. For the purposes of this paper these two populations will simply be referred to as “the students”. While not all chemical engineering university students receive formal education in this field, most chemical engineers can be expected to have to deal with corrosion damage in technical and/or managerial capacities. At the Royal Military College of Canada (RMC), CSE is an integral part of the Chemical and Materials Engineering program in the Department of Chemistry and Chemical Engineering.
2. Motivation for a Computer Based Corrosion Course

The main motivation for exploring a course of this nature is for distance learning applications, and more specifically, the potential of utilizing computer technology as a distance learning medium. The advantages and disadvantages of computer based learning (CBL) and more conventional education techniques have been presented in References 1 and 2. With a view to the future, the advantages and disadvantages of computer based distance learning relevant to a CSE course are considered to be:

**Advantages**

- Access to a large student and professional “market”
- Potential for achieving higher student cognition *
- Student interaction with course material **
- Direct linkages to Internet resources
- Higher student attention levels by stimulating multimedia presentations
- Rapid updating of information and course materials
- Tracking user interaction with the course material
- Efficient retrieval of specific information using electronic text processing **
- Optimization of a steadily shrinking expert instructor pool
- Wider choice of course offerings for students
- Freedom to follow individual pace * and learning styles for students
- Achieving special learning objectives through computer simulations (for example key technical concepts, role playing, decision making processes and their consequences) *

**Disadvantages**

- Lack of face to face interaction and engagement
- Low inspiration factor, especially when working in isolation
- Lack of teamwork
- Limited communication skills development
- Production of CBL material is (extremely) time consuming and costly *
- Need for special computing and software skills, mainly on the part of the developers *
- Requirement for expensive hardware *
- Non-uniformity of hardware affecting product quality
- Need for support staff *

* listed in Reference 1
** listed in Reference 2, with special emphasis on multi-media CBL
3. Course Objectives

The main course objective is to impart knowledge and understanding of corrosion and also, importantly, to equip students with the skills required to implement and manage corrosion control measures in their careers. For the practicing professional market, the latter aspect is particularly important. In this course the emphasis is on quantitative techniques in corrosion engineering and also on management issues of increasingly complex engineering systems.

In a study recently completed at the University of Southampton [3] it was concluded that computer based learning and teaching can be used successfully to teach engineering students knowledge and understanding of subjects and to improve their skill in using that understanding. As an example, it could be said that a student has a basic knowledge of corrosion measuring techniques and understands their underlying electrochemical principles but has not developed the skills to specify the most suitable technique(s) for a particular industrial application. Four elements of Bloom’s Taxonomy (application, analysis, synthesis and evaluation) are particularly relevant in this context.

The Southampton study included an application concerning phase diagrams and one concerning engineering design. In the former, the emphasis was on teaching knowledge and understanding, while the development of skills in engineering design was very important in the latter. Skill development was facilitated by students interrogating the system and deciding what information was most relevant, by the “creation” of an object they had never seen before, and in the process of converting information into accurate technical drawings.

4. Review of Existing Educational Products

Initially, it was envisaged that existing products such as general corrosion engineering text books could form the basis for the computer based corrosion course. Early efforts were thus focused on the design and development of a PC-based user interface. Four items were to form the front-end core (Figure 1): An information resource center, a corrosion testing laboratory, a management office and a field inspection and maintenance division. These are closely related to actual corporate structures for dealing with corrosion issues. As further detailed sub-components were specified, certain limitations of existing (mostly paper based) educational products became apparent:

- the treatment of corrosion and its control in mainly descriptive terms, as opposed to a more quantifiable approach;
- the relegation of management and economic issues to the fringes, with particular emphasis on technical issues;
- the limited treatment of emerging important methodologies in corrosion control, such as computerized information, knowledge based systems (KBS) and case based reasoning (CBR).
Historically, relative to other engineering disciplines, corrosion science and engineering has leaned towards the descriptive end of the spectrum, probably to the frustration of “outsiders” who may ask questions such as: “Why can’t this corrosion expert perform a calculation on how long this component will last.” Such sentiments are probably common in industry. Fortunately, progress is being made but the effort required to find proven quantified corrosion models or algorithms is considerable. Obviously, computer based learning (CBL) is ideally suited to exploiting such quantitative methods. Similarly, the emerging computer based methodologies (information systems, KBS, CBR etc.) lend themselves for incorporation into a computer based corrosion course.

It thus became apparent that, for a computer based course emphasizing quantifiable aspects of corrosion for the student and professional markets, new course material had to be designed and developed largely from “scratch”. Before proceeding to the electronic format, these materials needed to be developed and produced in paper based form.

5. Course Design and Development

The following systems approach [1] has been followed, which is also largely consistent with the basic course design methodology described in Reference [4].

Determination of target population market and topic area: These are the university students and practicing engineering professionals, and “corrosion science and engineering” respectively.

Target population (market) characterization: No previous corrosion knowledge is expected but a basic knowledge of calculus, physics and chemistry is assumed. Since the target population includes military personnel on duty on ships, overseas missions, remote bases etc., the course has to be self contained.

Formulation of objectives/learning outcomes: These have already been defined in Section 3 of this paper.

Choice and ordering of content [4]: In this process the need for substantial new course material development to satisfy the course objectives was realized.

Specification of teaching methods to achieve objectives: A solid theoretical foundation is provided to impart fundamental knowledge, using quantitative methods wherever possible. Understanding of the theory is enhanced by a detailed worked example involving application of the theory for each course module.

A most important element of the course is the use of situational case studies. Here the students are challenged to solve a real-world problems based on background information provided and the theoretical course components. Role playing, an important element of interaction strategies [5], is also introduced as part of the case studies. For example, in the
role of a plant manager, a student may have to defend his choice of maintenance strategy in the light of its consequences. Where possible, the case studies are based on high-profile, recognizable items to capture student interest. From the easily recognizable items, the student is drawn into the expert topics linked to each case study. Students are guided into using quantitative techniques and thus provided with real tasks and not merely exploring or browsing the course materials.

An example of such a case study assignment is presented in Section 6. There can be little doubt that case studies can be a very effective teaching tool in engineering. Cited benefits [6] include raised student interest levels and a sense of participation in real-world situations. These are particularly important for negating the low inspiration and lack of engagement criticisms which could be directed against CBL.

**Prototype construction and testing:** The paper based version of the course material developed to date currently serves as prototype model and is utilized at RMC by 4th year chemical engineering students. Selected sections are also included in a similar corrosion course presently offered at Queen’s University. The transformation of the paper based system into electronic format using object oriented (oo) PC software (Visual Basic 4.0) and World Wide Web (WWW) authoring tools (FrontPage 97) is underway. The “technical” problems that need to be overcome with the state of existing hardware and software are easily underestimated. A conservative approach based on the lower end of user hardware platform sophistication is being adopted. It is unreasonable to assume that the target population will have access to the latest hardware or software products.

**Implementation:** The transition from the paper based course material into electronic format is a gradual one. Initially, computer applications assume a supplementary role only. It may take several more years for the entire course to be presentable as a stand-alone computer based package. However, more specialized sections, such as marine corrosion can be offered to the professional market within relatively short time frames.

**Evaluation, feedback and revision:** The importance of independent course evaluation, outside the influence sphere of the instructors has been recognized. Apart from formalized course evaluations by students, a review process of the courseware by independent experts from industry and academia is appropriate.

6. **Example of a Case Study Assignment - Corrosion Damage to the Statue of Liberty**

**The Paper Based Format**

Following an introduction to the history of the Statue of Liberty, the construction techniques and materials used, in-service corrosion problems, details of a major refurbishment program completed in 1986 and associated costs, the following assignment has to be completed by students. The necessary theory and a detailed worked example are included in the atmospheric and aqueous corrosion modules of this course. It should be
noted that several questions are styled to ultimately facilitate computerized marking, essential for very large student classes.

**Your Atmospheric Corrosion Assignment**

1. Identify the two main corrosive agents responsible for the overall corrosion damage to the statue from the following list.

| Carbon dioxide from industrial and urban activity |
| Nitrous oxides from industrial and urban activity |
| Rain water |
| Wind swept chlorides in combination with thin moisture films |
| Sulfur dioxide from industrial and urban activity in combination with thin moisture films |

2. Given the above background information, select the three highest corrosion risk areas on the Statue of Liberty from the following: *Hint: the statue was never “water-tight”.* For example, significant leakage took place through the torch where additional lights had been retro-fitted. The arm was also perforated, where a spike from the misplaced head reportedly had abraded the copper skin [7].

| The armature, where it joins the skin |
| The skin, in contact with the armature |
| The central pylon |
| The exterior of the skin |
| The riveted joints in the skin sheets |
| The interior of the skin, where moisture is trapped |

3. Given a copper atmospheric corrosion rate of 0.006 mm thickness loss in the statue’s environment after one year of exposure and 0.015 mm after ten years of exposure, determine the total thickness loss of the copper skin over a 100 year life time. Express your answer as a percentage of the original skin thickness. *Hint: Use the linear bilogarithmic law to calculate the thickness loss over the first twenty years of exposure. For the subsequent 80 years, you can assume that the rate in year No. 20 is maintained on average.*

| More than 50 % |
| About 10 % |
| About 2 % |
| Less than 1 % |
4. a. What is the patina on the statue and how does it affect the corrosion rates?
   b. Do you recommend cleaning the copper skin to a bright finish as part of the 100-year restoration work?

5. Consider the polarization diagrams in Figure 3, for copper and iron in 3.5% NaCl solution at ambient temperature.
   a. Given the indicated free corrosion potentials of copper and iron, what are the respective corrosion rates in mm/year for these two metals in the uncoupled condition?
   b. If the two metals are brought into contact to form a galvanic couple, by what factor is the corrosion rate of iron increased, assuming an area ratio of 1:1?

6. What main steps would you recommend as part of the restoration work to minimize future corrosion damage, assuming a budget similar (in current terms) to that of the actual restoration project could be raised?

7. a. Given the corrosion rate information for the first year in Question 3, what ISO corrosion category does the statue environment fall under?
   b. Is this an expected result?
   c. Using the ISO guidelines, indicate the expected corrosion rate of an aluminum statue skin in the first year?

**The PC based format**

The computerized version utilizes hypertext and graphics hotspots to facilitate student interaction with the assignment and fundamental course materials, as shown in Figure 2. The process is started by merely “clicking” on items presented on the Start-Up Page. The corrosion laboratory module would contain relevant corrosion test procedures and data, such as the polarization diagrams required in Question 5 of the assignment. Specialist advisors provide students with detailed information on selected topics such as the formation of the patina. It is apparent from Figure 2 that the students can be drawn easily into the expert topic material, at the core of the course modules. Each student’s progress through the different links could be monitored and access to certain items could be blocked, if pre-requisite sections have not been completed.

**7. Summary and Conclusions**

The potential advantages of a computer based corrosion course over more conventional course offerings are numerous, from the perspective of both provider and user. However, there are also several disadvantages, one of these being the enormous effort in professional time that has to be invested in developing such a course. To meet specific
course objectives, the design and development of new course material was required. A so-called systems approach was followed to produce this material, in paper based format initially. Case studies, simulating real-life corrosion problems are an important element of the course, designed to interest and engage students in the core subject matter of each module. The transformation to a stand-alone computer based format is a gradual one.

8. References

3. J.D. Bailey, “The Integration of Hypermedia Based Learning Applications into Undergraduate Engineering Degree Courses”, Ph.D. Thesis, Faculty of Engineering, University of Southampton, May 1996.

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Figure 1 Initial design concept for the front-end of the computer based corrosion course
Assignment Module 2

Corrosion on the Statue of Liberty

Question 2
After consulting the background information select the three highest corrosion risk areas on the statue from the following list.

Question 3
Given a copper atmospheric corrosion rate of 0.006 mm thickness loss after one year of exposure and 0.015 mm after ten years of exposure, determine the total thickness loss over a 100 year lifetime.
Use the linear bilogarithmic law for the first twenty years of exposure. Thereafter you can assume that the rate has stabilised.

The design of the statue, which rises more than 91 meters into the air, essentially involves a rigid central pylon and a secondary frame, to which further framework, the so-called armature, and the skin are attached (Fig. 1). The skeleton was manufactured out of wrought iron, a common construction material of that era...........

A. The armature where it joins to the skin
B. The skin, in contact with the armature
C. The central pylon
D. The exterior of the skin
E. The interior of the skin, where moisture is trapped
F. The twisted joints in the skin sheets

Module 2 Atmospheric Corrosion
2.4.3 Atmospheric corrosion as a function of time

Pourbaix [24] presented the so-called Linear Bilogarithmic Law for Atmospheric Corrosion, to describe atmospheric corrosion damage as a function of time on a mathematical basis. This law was shown to be applicable for different types of atmospheres and a variety of alloys.
According to this law, \( \log(p) = A + B \log(t) \), where \( p \) is the corrosion ..............

Figure 2 Conceptual design of a real-life corrosion case study in the computer based corrosion course