The Development and Teaching of Corrosion Course in an Engineering Program

Susan Caines and John Shirokoff,
Faculty of Engineering and Applied Science
Memorial University of Newfoundland
sjc184@mun.ca; shirokof@mun.ca

Abstract -The development and teaching of a corrosion course that includes laboratories in a senior level engineering program is outlined and discussed with respect to their learning outcomes, graduate attributes, assessment and practical value. The laboratory course of study complements the overall course in terms of building on a student's background in electrochemical theory, corrosion concepts, engineering practice, analyzing data, and comparing measured data to theory.

Keywords: Laboratory, Graduate attributes, Learning Outcomes.

1. INTRODUCTION

Mechanical and process engineering students at Memorial University of Newfoundland have the option to take a final year (term 8) corrosion course that includes laboratories. The course of study at Memorial has traditionally involved chemistry courses for mechanical and process engineers and in the final year there is a corrosion course offered. The corrosion course includes 3 one hour lectures per week and 1 three hour laboratory period per week over the 15 week semester. The outline for the corrosion course includes the use of a detailed corrosion textbook inclusive of corrosion theory, practice, applications and references [1]. In order to supplement the student's practical background, the laboratory experiments are designed to link hands-on corrosion experimentation with theory presented in the lectures, textbook and in some cases their industrial work experience on student work-terms.

Laboratories can be used to give students an opportunity to apply theory and gain valuable experience. Feisel et al [2] discuss how limited learning outcomes can reduce the effectiveness of a laboratory.

Learning outcomes are important to focus course delivery and ensure that students understand the course expectations. Outcomes are developed to help ensure that students learn what is required, outline what the expectation is for faculty when designing delivery, and can be used to demonstrate to the profession that a program will develop future engineers that are ready to join the workforce [3].

2. DEVELOPMENT AND OUTLINE

Communication is an important aspect of offering university courses. On the first day of classes a detailed course outline is given to the students so that they are clear on the course components, objectives, learning outcomes, marking scheme and assigned tasks that are an integral part of the course assessment process. Additional information includes a statement on communication which reads as follows "Statement of preferred method of contact: email, D2L contains some materials: course outline, course notes from textbook, and laboratory manual." The course calendar entry, course description, and major topics are well defined in the course outline and describe significant course components. It creates a logical guide and plan of study for the students during the semester.

Calendar Entry: ENGI 8911 Corrosion and Corrosion Control examines forms of corrosion; the electrochemical nature of the corrosion process; the mixed potential theory, Pourbaix diagrams and Evans diagrams; corrosion testing, control use by use of materials, selection, cathodic protection, inhibitors, and coatings. There are case studies and selected corrosion problems.

Course Description: ENGI 8911 Corrosion and Corrosion Control uses a textbook that is suitable

for a senior to graduate level course of study on the corrosion of metals and it has more information than would be included in a fifteen-week semester course. The textbook has fifteen chapters of which 1-4 and 6-12 will be covered in the lectures, with time permitting. Chapters 13-15 may also be covered as additional topics for summary-presentations from the research literature by groups of student (about 2 students per group). There are five laboratory sessions that measure basic corrosion mechanisms, several different types of Tafel plots, corrosion protection by sacrificial anodes and impressed potentials.

Corrosion course major topics:

- Technology and Evaluation of Corrosion
- Electrochemical Thermodynamics and Electrode Potential
- Electrochemical Kinetics of Corrosion Passivity
- Galvanic and Concentration Cell Corrosion
- Pitting and Crevice Corrosion
- Environmentally Induced Cracking
- Effects of Metallurgical Structure on Corrosion
- Corrosion-Related Damage by Hydrogen, Erosion, and Wear
- Corrosion in Selected Environments
- Atmospheric Corrosion and Elevated Temperature Oxidation
- *Cathodic Protection (Test Methods in Cathodic Protection)
- *Coatings and Inhibitors (Protective Coatings and Chemical Treatment)
- *Materials Selection and Design (Materials for Industrial Applications)

*Potential topics for Summary Presentations from Research Papers (Process Industries, Oil and Gas, Tar Sands, Pipelines, Petrochemical, Forestry, Mining, Offshore-Marine-Naval-Ships, Manufacturing, Transportation, Food Processing etc.)

These major topics are used to develop laboratories to complement student learning. These laboratories are:

- Basic Corrosion Mechanisms: Exploring galvanic corrosion by developing a galvanic series and exploring the effects of ion and oxygen concentrations.

- Introduction to Tafel Plots: Study of the anodic and cathodic processes and introduction of equilibrium potentials and their relationship to free corrosion potential.
- Intermediate Tafel Plots: Further understanding of potentiostatic measurement through experimentation with dissimilar metals
- Tafel Plots: Examination of polarization, overpotential, and the effects of electrolyte on corrosion potential.
- Corrosion Protection by Sacrificial Anodes and Impressed Currents: Examination of protection strategies using simulated buried pipelines.
- Materials Characterization: The Study of Corrosion Products: Introduction to techniques to identify corrosion products including X-ray diffraction, Optical Microscope and scanning electron Microscope.

An additional method to increase student engagement with the theory is the implementation of student presentations. These summary-report-presentations involve research using the QEII library (journals, conference proceedings), the world-wide-web (www), and related internet resources to access and obtain a research paper-topic of interest that can be reviewed properly and made into a presentation to be presented to the class towards the end of the semester by small groups of students (i.e. number of students/group will depend on the size of the class).

3. RESULTS AND DISCUSSION

Graduate attributes are developed to ensure engineering graduates complete their education with a strong understanding of not only engineering principles but many other skills that are vital to success in the engineering profession. These important skill categories were developed in consultation with engineering professionals. Memorial University is committed to fully incorporating these attributes into the curriculum and courses are designed and evaluated to satisfy these requirements. The corrosion course contributes to this initiative.

Based on the corrosion course material with respect to the overall engineering curriculum for

mechanical and process engineers the following learning outcomes, graduate attributes and level of understanding expected, were identified as described in table 1.

This connection to graduate attributes ensures our graduates enter the engineering profession with all the skills needed to be successful.

Table 1: Learning outcomes, graduate attributes and level, and assessment.

Learning Outcome	Graduate Attribute and (Level)
Explain basic corrosion processes.	A knowledge base for engineering, (Intermediate)
Describe and identify types of corrosion.	A knowledge base for engineering (Advanced)
Electrochemical theory (thermodynamics, kinetics, potentials).	A knowledge base for engineering (Advanced)
Concepts of passivity, concentration cells, pitting, crevice corrosion.	A knowledge base for engineering (Advanced) Problem analysis (Advanced)
Assess corrosion resistance of a variety of materials in varying environments.	A knowledge base for engineering (Advanced) Problem analysis (Advanced)
Understand factors that contribute to corrosion resistance.	A knowledge base for engineering (Advanced)
Discriminate among corrosion protection systems.	A knowledge base for engineering (Advanced)
Analyze corrosion data.	Investigation (Intermediate) Use of engineering tools (Intermediate)
Compare theoretical and measure data.	Investigation (Intermediate) Use of engineering tools (Intermediate)

The laboratory portion of this course also addresses the graduate attributes of individual and team work, communication, and impact of engineering on society and the environment. Labs are conducted in groups and the teams must analyze data and draw conclusions within their groups. The results are communicated in a formal report; students are expected to use a professional format and technical language and

are evaluated on this criteria. This helps the student improve their written communication skills and prepares them for professional report writing. The final lab in the course addresses the impact of engineering on society. This lab deals with the real issue of buried pipeline leaks and their impact on the environment. Corrosion is a known cause of leaks in buried pipes [3, 4] and this lab is designed to highlight the importance of corrosion protection and the dire impact of corrosion on society. Anecdotally, this is the most interesting laboratory for the students and draws the most enthusiasm.

The presentation is completed in groups and improves students' communication skills, and team work; both graduate attributes important to the engineering profession. Students present a relevant review of a scholarly paper that deals with corrosion control and prevention. This is an opportunity to work with peers and design an engaging presentation that demonstrates their understanding of corrosion. Students are evaluated on engineering content and understanding but also on communication skills. Presentation skills are understood to be important in the engineering profession and the ability to communicate ones ideas is vital to a successful engineering career.

4. CONCLUSION

Graduate attributes are an important part of modern engineering education. ENGI 8911, Corrosion and Corrosion Control was developed to incorporate many of the graduate attributes including:

- A knowledge base for engineering
- Problem analysis
- Investigation
- Use of engineering tools

Informally, the course also touches on other attributes; individual and team work, communication skills, and impact of engineering on society and the environment.

This course demonstrates the successful integration of graduate attributes into a corrosion course.

5. NEXT STEPS

To further improve the course and improve student engagement, additional laboratories are being considered and developed. Opportunities to apply theory in real life ways are needed to keep the students interested and demonstrate the importance of corrosion to their future careers.

References

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