Design of an Asynchronous Internet-Based Course for Advanced Placement Chemistry Teachers

William R. Robinson

Department of Chemistry, Purdue University, 1393 Brown Building, West Lafayete, IN 47907, wrrobin@purdue.edu

Abstract: This paper may be of particular interest to readers who are interested in designing the non-laboratory portion of an Advanced Placement (AP†) Chemistry workshop and/or interested in a basic design for a simple asynchronous distance-learning Web site.

The design, organization, delivery, and results of a course for high school AP chemistry teachers are presented. The course, *Concepts of AP Chemistry*, was delivered as an eight-week summer program by a combination of two methods: a textbook and the Internet. Its principal objectives were to help teachers to review selected concepts; to understand the breadth, depth, and subtlety of the AP examination as well as the motivation, ability, and dedication required of AP students; and to access course-related information via the Internet. A secondary objective was to expand the participants's familiarity with technology suitable for use in their courses. A Web site and list server were used for communication. The Web site was the source of assignments and links to resources. E-mail and the list server were used to discuss assignments and to post questions and comments from participants. Participants returned assignments by email.

Introduction

The Advanced Placement (AP) Program is a College Board program for bright, motivated students who take college-level courses in high school [1]. Advanced credit at many colleges is available for students who score well on the national AP examinations given each spring. During the 1998–99 academic year 704,289 students from 12,886 high schools prepared for and wrote 1,149,151 exams in 33 different AP courses [2].

In 1990 the Indiana General Assembly required that by 1996 high schools begin offering advanced placement courses in English, math, and at least one science, and the state began to pay the fee for students who took these AP examinations. The program has been successful in encouraging high schools to offer AP courses and students to take AP examinations. In 1990, the last year students paid for examinations, a total of 2333 AP examinations were taken in Indiana with 669 in mathematics and science. In 1996, the total was 14,263, of which approximately 10,000 were in subjects supported by the state. Indiana was 27th in the proportion of students taking AP exams (97 exams per 1000 students).

Unfortunately, the success rate of Indiana students is not good. In 1996 the percentage of well-qualified and extremely well-qualified Indiana chemistry students, as determined by their scores on the AP examination, was one-fourth of the national average.

In recognition of the fact that few of Indiana=s teachers have taught AP courses, the state also began to support one-week summer workshops for AP teachers at state colleges and universities. As part of Purdue University=s School of Science Outreach Program, the Department of Chemistry has provided summer workshops since 1990. The chemistry workshops review highlights of bonding, kinetics, equilibria, thermodynamics, electrochemistry, and nuclear chemistry. Participants complete ten laboratories that are appropriate for high school AP courses. Various models for organizing an AP course are discussed, as are the grading of AP exams and the level of performance that is expected of students.

The summer workshops have been well-received, but they do have limitations. Teachers state that a one-week workshop provides insufficient time for review of concepts. This, coupled with the inability of some teachers to leave home to attend a workshop, led us to develop the eight-week, content-centered, Web-based summer course for AP chemistry teachers described herein.

This paper describes the objectives of the course and the reasoning behind the selection of these objectives, the delivery system implemented to meet the objectives, and some teacher responses.

Course Objectives

Our course objectives were developed from observations of and discussions with new AP teachers in our summer in-house workshops, from their comments concerning the workshops, and from listening to successful AP teachers with significant experience. The six objectives and rationales for these objectives follow.

Review the Concepts Commonly Found in a Second Semester General Chemistry Program for Science and Engineering Students. The content of the second semester of a typical general chemistry course for science and engineering majors is a significant component of the AP examination [3, 4]. In many high schools these topics are either not introduced in the first-year chemistry course or not taught at an AP level. Because AP courses are regarded as Aplums,@ new teachers may wait several years before they have an opportunity to teach an AP course; thus, many new AP teachers find their concepts are rusty because they have not used them in the

† AP is a registered trademark of the College Entrance Examination Board which does not endorse this product.

 S1430-4171(00)05410-8, Published on Web 08/06/2000, 10.1007/s00897000410a, 55026wr.pdf

classroom for several years. In Indiana the problem was aggravated by the lack of participation of a majority of high schools in the AP program prior to 1990; there were few AP courses to teach.

As part of our review we asked participants to refresh their concepts using a textbook of their choice; complete a problem set consisting of questions from old AP examinations, conceptual essay questions, and problems; and write AP-like examination questions over the concepts covered. Participants were told they should feel free to discuss the problem sets with other participants or with me by email and/or our list server. Answers to the problem sets were returned to me by email. If a question contained a calculation, participants provided both the answer and a step-by-step verbal description of how to arrive at the answer. I reviewed the answers and pointed out sections that were incorrect (but did not indicate what was incorrect) and asked participants to correct them. Their AP-like multiple choice questions, essays, and problems, with their answers and verbal description of how to arrive at the answers, were posted on our list server for discussion.

Develop Pedagogical Content Knowledge Through a Study of the AP Examination and the AP Program=s Expectations of Students. Successful AP chemistry teachers understand not only chemistry content but also the breadth, depth, and subtlety of the AP examination; the motivation, ability, and dedication required of AP students; the pace required to cover all of the topics necessary in an AP course; and a variety of techniques that they can use to help their students optimize their performance on the examination. All of these issues fall into the realm of pedagogical content knowledge (PCK), which Shulman [5, p 9] describes as, "…for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations—in a word, the ways of representing and formulating the subject that make it comprehensible to others…. [It] also includes an understanding of what makes the learning of specific concepts easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning."

Many of the activities in our course were designed to improve the participants=s pedagogical content knowledge. For example, we have talked with many new AP teachers who use only one type of testing, free response testing with questions that address a single topic. Consequently, their students have no experience with multiple-choice questions or questions with a mixture of topics. Many successful AP teachers use a variety of types of questions and give students a great deal of practice taking AP-like exams. The requirement that participants work problems from old AP examinations and write AP-like questions and problems was designed to introduce them to the various types of questions used and to give them practice writing such questions in a situation where discussion was possible. An introduction to the AP chemistry list server provided another source of PCK, that is, other AP teachers.

Make Connections with Other Teachers and Discuss Issues Related to Their Courses. According to participants, one of the most satisfying aspects of face-to-face AP workshops is the exchange of ideas among the participants. It was our intent to provide our participants with a vehicle to hold these discussions over the Internet. In addition they were introduced to the College Board=s AP chemistry list server, a valuable source of advice and information from other AP teachers.

Develop Technological Skills and Use the Internet as a Resource. Many of the teachers in our face-to-face workshops graduated before the use of personal computers and Internet access became common. Often, these teachers are not familiar with the power of these tools and the access to information these computers provide. As part of our online workshop we introduced spreadsheets as useful tools for teaching, both as calculation and graphing aids and required participants to use information obtained from the Internet.

Identify and Use Web Sites That Provide Chemistry Content and Sites That Offer Information and Advice about the AP Program. There are a variety of Internet sites that provide information about the AP chemistry program and resources that can be used by AP teachers and students. Our participants used information from these sites as part of their assignments.

Apply concepts to new, real-world situations found on the Web. This objective really is not essential for teaching an AP course. It was included because AP teachers generally teach introductory chemistry classes in addition to AP classes and students in the introductory classes benefit from real-world examples. Writing questions based on chemistry-related Web sites introduced teachers to such sites.

Course Participants

Publicity for the course was focused on Indiana teachers although the course also was announced nationwide. In addition to announcing the program by mail to every high school chemistry teacher in the State of Indiana, we distributed pamphlets at the Hoosier Association of Science Teachers meeting and announced the program over the AP list server. In order to insure that potential participants had at least a minimal familiarity with electronic communication, these announcements provided an email address for requesting additional information. Inquiries were received from 14 states, including Indiana, and from Canada.

The course was offered for variable credit through Purdue University=s continuing education program. Participants or their schools paid tuition to enroll in the course. Those who dropped received refunds according to University guidelines.

Participants could select one or more of the following pairs for one credit per pair: (a) Equilibrium and Solutions (b) Thermodynamics and Electrochemistry (c) Kinetics and Nuclear Chemistry. For each topic in a pair they were instructed to review the relevant concepts and: (a) complete a problem set with AP examination questions and conceptual questions and problems; (b) create a new AP-like essay question drawn from data available on the Web and post the question and answer.; (c) create a new AP-like free-response problem drawn from data available on the Web and post the question and answer.; (d) create two new multiple choice questions and post the questions and answers; and (e) use a spreadsheet program to manipulate a set of data and draw conclusions. The various styles of AP questions are described in Appendix 1.

Ultimately, ten participants enrolled in the course: eight from Indiana, one from New Jersey, and one from Michigan. Of these, three dropped the course; one with two other summer

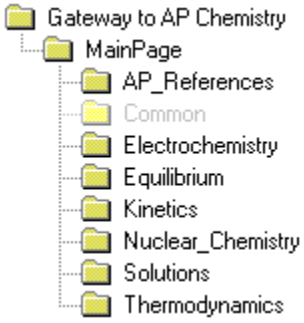

Figure 1. Site Map of the Concepts on the AP Chemistry Web Site.

courses, one who claimed problems with their Internet provider, and one who tried to work at a summer cottage on the lake and admitted the distraction was too much. Each of the remaining seven participants completed their assignments satisfactorily, although some items required several iterations.

Design of the Delivery System

Concepts of AP Chemistry was designed as an asynchronous course for motivated technovices working at home with 14 or 28 K modems. Consequently, we made no attempt to deliver content over the Internet; participants used texts to review concepts. The Web site served as a means of providing assignments and identifying resources. We used neither graphics, animations, nor buttons (we used text links) and only two small banners per chapter in order to keep the bandwidth as narrow as possible. The site design followed principles described by Lynch and Horton [6].

To accommodate our inexperienced users, we kept the navigation as simple as possible. The site is organized into chapters, a familiar concept, with minimal links between chapters. A link to the home page is included on every page. E-mail was used for communication between the instructor and individual participants and a list serve for general communication. We also selected several sites as information sources so we could require participants to use the Web.

Site Structure

The site structure is outlined in Figure 1.

Gateway. Gateway contains two pages: "Gateway to AP Chemistry," the login page participants see when they enter the site and a page containing a description of the course that serves as an information page for prospective participants.

Main Page. "MainPage" is a folder that contains complete information about the organization of the workshop and of the site. The first page of the folder, "The AP Chemistry Home Page," is the home page for participants in the course. This page describes navigation within the site, expectations of participants, organization of the course, organization of the site, and how to use email and the listserv. The first page also contains links to other pages in the folder and links to the "AP References" folder and the six content folders of the site.

Within the "MainPage" folder are the site map shown in Figure 1, instructions for completion of the exercises found in the various content chapters, and a guide to using email to discuss chemistry. The instructions for exercises describe the styles and complexity of the various questions (multiple choice, free-response problems, and essays) found on AP chemistry examinations. These instructions are available in Appendix 1. The guide to using email to discuss chemistry provides participants with a standard protocol that compensates for the absence of subscripts, superscripts, and symbols in basic email packages. It is available in Appendix 2.

As the course progressed, additional information was added to the site and posted in a section called "New Items" located at the head of the home page so that participants see the links to this new information when the enter the site.

AP References. "AP References" is a folder that contains information about the AP program and the AP examination as well as links to Web sites that contain old AP examinations (with answers) and information that may prove useful to the teacher and students. This information includes an outline of topics for the AP examination provided by the College Board; links to the AP chemistry Web site and to the AP chemistry list server maintained by the College Board and to AP Web sites provided by other AP teachers; an analysis of the types of problems, reactions, and essays from past exams; a set of advice from an experienced AP teacher to students containing keys to passing the AP exam; items from past AP exams with scoring rubrics; a distribution of scores for the problems on the past year=s AP examination; and average Indiana and national AP scores.

"Common" Folder. The "Common" folder contains images that are displayed at the top of the pages and any other images that occur on other pages. Participants do not have access to this folder.

The Six Content Folders. The "Electrochemistry," "Equilibrium," "Kinetics," "Nuclear Chemistry," "Solutions," and "Thermodynamics" folders are the content folders of the site. Each of these folders is structured in the same way and contains a home page with an outline of the parts of that topic covered on the AP examination, links to assignments for the topic, and links to web sites related to the topic. The content of the "Thermodynamics" folder is described as an example.

The "Thermodynamics" home page repeats the list of thermodynamics topics that should be covered in an AP program, contains links to the projects expected from the teachers in the course, and contains a list of references with links to .com, .gov, and .edu sites that describe concepts and applications of thermodynamic principles. The thermodynamics problem set contains an AP essay question and an AP free-response problem from recent AP examinations as well as a series of thermodynamics exercises from a variety of general chemistry sources. The references to concepts and applications of thermodynamic applications contained 15 links to sites that included, among others, the Chemistry Web book by The National Institute of Standards and Technology (NIST), the program REACTION, which calculates changes in the thermochemical functions; a NASA publication that identifies one way thermodynamics is used in the space program; a discussion of the origin of the Celsius temperature scale and of difficulties in calibrating a thermometer; and a set of physical and thermochemical data for a maneuvering fuel used in the space shuttle. A complete set of these thermodynamics links is available on the Web site.

Course Outcomes

There were problems associated with our course that were similar to problems observed by Liu, Walker, and Brooks [7]

during their Internet course on small-scale laboratory activities for high school teachers. Dealing with the new technology was a problem for several of our participants. Others participants were Asoftware-challenged@ to use Brooks=s term, and were not familiar with the use of email, list servers, or spreadsheets programs. Some had limited access to email. In fact, one participant who dropped cited problems with their Internet Service Provider (ISP). However, as participants comments indicate, we believe that *Concepts of AP Chemistry* accomplished many of its objectives.

Participants Reviewed the Concepts Commonly Found in a Second-Semester General Chemistry Program for Science and Engineering Students. Completing problem sets and writing free response questions provided participants with a reason to review concepts and renew their familiarity with the material. As one wrote, AWhen I referred to the text book I use it was right there. Guess I need to read the text more myself.@ These assignments also helped participants identify rusty conceptual understanding. Another wrote, AI rechecked my equilibrium problem set and saw the errors of my ways.... On the electrochemistry problem set, I saw my exponent mistake....@ In response to one of my corrections I received the following reply, "Regarding kinetics problem number 2, I finally see the light, and now that I do I'm not sure why I tried to make the problem more difficult than it is. I guess I was fooled.@

Participants Increased Their Pedagogical Content Knowledge Through a Study of the AP Examination and the AP Program=s Expectations of Students. The high level of performance expected of their students became apparent as participants wrote and worked problems and thought about their schedule. They also discovered the complexity of AP problems, as described in Appendix 1. One participant commented about one question from an AP examination, AEach of us so far has worked this problem a different way. I fear a problem like this, which yields so many interpretations, is a rather unfair choice for an AP exam question.@ This comment gave us an opportunity to make the point that AP courses are more difficult than typical second-year courses. It became apparent that many teachers did not realize the depth of AP questions and some balked at using such questions in their classes. However, they came to realize the need for doing so, probably more due to information they saw on the AP list server than information from me. The fast pace required of their courses also became apparent.

Participants also came to recognize different ways to approach teaching AP chemistry. As one of the participants noted, AHaving seen my students performance on this years AP exam, a disappointment, I am looking forward to putting into practice what I have learned this summer.@ Another saw value in the spreadsheet problems, "Thank you for sharing these problems. I see a real value to them. Creating the spreadsheets helps to reinforce the concepts for the kids. And the graphs help them >see= the concept.@

Participants Made Connections with Other Teachers and Discussed Issues Related to Their Courses. The Internet was used to discuss issues related to participants= courses. Informal discussion on the course list server covered selecting students for an AP course, scheduling, testing, grading, motivation, and laboratories. In addition, we discussed the need for exposing students to the different types of questions and asking questions at the same level found on an AP examination.

Participants Developed Technological Skills and Used the Internet As a Resource. It was apparent that the participants' facility using email, the Internet, and spreadsheets improved. After the first two weeks there were no more comments like the following, AI am just trying out the email again here at xxx.com to see if I can reach you this time.@ and AI just sent my introduction to the list, and the resulting output of my job was very strange. It read '….' Did I do something wrong? I am new at using email so I would appreciate any guidance that you can me.@ Participants continue to use the AP list server, as evidenced by their contributions to the list.

Participants Identified and Used Web Sites That Provide Chemistry Content and Sites That Offer Information and Advice about the AP Program. It was not possible to complete their assignments without accessing several of these sites and all of the participants who completed the program completed all assignments.

Acknowledgment. I wish to acknowledge support from The Indiana Partnership for Statewide Education and Purdue University, training and assistance from the Office of Distance Learning and the Multimedia Instructional Development Center at Purdue University, and registration and other paperwork by Purdue University=s Center for Instructional Excellence. I owe a particular debt to the participants for their patience and willingness to experiment, to Ms. Patsy Mueller who introduced me to the AP teacher=s experience, and to all of the AP readers from whom I have learned and come to appreciate the effort and dedication that goes into a successful AP course.

Appendix 1. Instructions for Problem Sets, Problems, Essays, and Multiple Choice Questions

Instructions for Problem Sets. Please feel free to discuss questions and problems with other participants or with me by email and/or our list server. E-mail me your final answer to the problem sets. If the question is a calculation, send the answer and a step-by-step description of how you arrived at the answer; you need not try to type in math. (Examples followed these instructions and illustrated appropriate answers and showed how to set chemistry in email without the use of superscripts or subscripts.)

Instructions for Free Response Problems. Write your problems in the style of the AP examination. AP problems are set so that students really must understand the material to solve the problem. These questions: (a) are presented in such a way that students who solve problem by invoking an algorithm without understanding will not be successful, (b) may contain too much information, (c) require more than simple recall, and (d) often require students to use concepts that come from topic areas that are not directly related to the main topic of the question.

Consider question 3 from the 1997 examination [8]: In an electrolytic cell, a current of 0.250 ampere is passed through a solution of a chloride of iron producing Fe(s) and Cl_2(g).

(a) Write the equation for the reaction that occurs at the anode.

(b) When the cell operates for 2.00 hours, 0.521 gram of iron is deposited at one electrode. Determine the formula of the chloride of iron in the original solution.

(c) Write the balanced equation for the overall reaction that occurs in the cell.

(d) Calculate the current that would produce chlorine gas at a rate of 3.00 grams per hour.

Notice the subtleties in this problem. Students must apply the definition of an anode, not just recall it. Part (b) is a stoichiometry problem embedded in an electrochemistry problem and requires a nontrivial chain of logic: amps and time give moles of electrons reacting with iron ions; mass of iron gives moles of iron atoms and ions; moles of electrons and moles of iron ions give charge on iron ions; write formula from the charge on an iron ion and the charge on a chloride ion. Part (d) looks like a rate problem but it is a stoichiometry problem coupled with an electrochemistry problem.

Tables containing commonly used chemistry equations are provided with each examination for students to use when taking the free-response section. The availability of these equations means that in the scoring of the free-response sections, little or no credit will be awarded for simply writing down correct equations or for ambiguous answers unsupported by explanations or logical development.

Instructions for Free-Response Questions (Essays). Write your free-response questions in the style of the AP examination. AP free-response questions are set so that students really must understand the material to answer the question, they can not simply use memorized definitions and explanations. These questions may: (a) use words in such a way that students who try to recognize a question topic from the language without understanding (i.e., students who use code words to prompt responses) could be misled, (b) contain information that is not required to solve the problem, (c) require more than simple recall, (d) cover several topics and require students to use concepts that come from topic areas that are not directly related to the main topic of the question.

For example, consider Question 7 from the 1997 exam [8]: For the gaseous equilibrium represented below, it is observed that greater amounts of PCl_3 and Cl_2 are produced as the temperature is increased.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

(a) What is the sign of $\Delta S°$ for the reaction? Explain.

(b) What change, if any, will occur in $\Delta G°$ for the reaction as the temperature is increased. Explain your reasoning in terms of thermodynamic principles.

(c) If He gas is added to the original reaction mixture at constant volume and temperature, what will happen to the partial pressure of Cl_2? Explain.

(d) If the volume of the original reaction is decreased at constant temperature to half the original volume, what will happen to the number of moles of Cl_2 in the reaction vessel? Explain.

First, this question starts off like an equilibrium question ("For the gas phase equilibrium represented below..."), however, parts (a) and (b) turn out to be thermodynamics questions. Second, it indicates that the amount of products increases as the temperature is increased but this information is not necessary to answer the question. In fact, the information is part of the answer to part (b). The majority of the question tests thermodynamics, but part (c) invokes the concept of partial pressures of gases and part (d) invokes gas laws. Finally, future AP exams will not contain questions like "What is the sign of $\Delta S°$ for the reaction?" This is a coin-flip question; a student has a 50/50 chance of getting the correct answer. Future exams will focus on the explanation and not give credit for the correct sign.

Instructions for Multiple-Choice Questions. The purpose of the multiple-choice questions is to assess the breadth of a student's knowledge and understanding of the basic concepts of chemistry. AP multiple-choice questions are not simply definitions, may use the same answer twice, require application of recalled information and not just simple recall, may require a student to create an answer rather than simply to recall something or to activate an algorithm., and emphasize conceptual understanding as well as qualitative and simple quantitative applications of principles. Calculators are not permitted on the multiple-choice sections of the AP Chemistry examination; however, the knowledge of many basic definitions and principles, expressed as equations, is a part of the content of chemistry that students should learn and this knowledge will continue to be assessed in the multiple-choice section. Any numeric calculations involving these fundamentals in the multiple-choice section will be limited to simple arithmetic so that they can be done quickly, either mentally or with paper and pencil. In some questions the answer choices differ by several orders of magnitude so that the questions can be answered by estimation.

Appendix 2. Conventions for Using E-mail to Discuss Chemistry

Write subscripts on line: F_2 becomes F2.

Use a caret, ^, to indicate a superscript: S^{2-} becomes S^2-.

Use -> to replace an arrow in a reaction. 2 H2 + O2 -> 2 H2O.

Use = to replace a double arrow in an equilibrium: HF = H^+ + F^-.

Spell out Greek letters: [delta]S.

Use X to indicate multiplication: 2 X 2 = 4.

Use / to indicate division: 6/3 = 2.

Type the atomic number before the symbol for a nuclide and the mass number after it using hyphens: $^{24}_{12}Mg$ becomes12-Mg-24.

References and Notes

1. The College Board, New York, NY. The College Board Online, The Advanced Placement Program (AP). http://www.collegeboard.org/ap/ (accessed May 22, 2000), email: ap@collegeboard.org.
2. The College Board, New York, NY. The College Board Online, Understanding How AP Works. http://www.collegeboard.org/ap/techman/chap1/table1.1.htm (accessed May 22, 2000) email: apexams@info.collegeboard.org.
3. Taft, H. L. *J. Chem. Educ*. **1997,** *74,* 595–599.
4. Taft, H. L. *J. Chem. Educ*. **1990,** *67,* 241.
5. Shulman, L. S. *Educational Researcher* **1986,** *15,* 4–14; cited in Cochran, K. F. University of Northern Colorado, Greely, CO.

Research Matters—to the Science Teacher: Pedagogical Content Knowledge: Teachers' Integration of Subject Matter, Pedagogy, Students, and Learning Environments. http://www.narst.org/research/pck.htm (accessed May 22, 2000).

6. Lynch, P. J.; Horton, S. Yale University School of Medicine, New Haven, Connecticut. Web Style Guide. http://info.med.yale.edu/caim/manual/index.html (accessed May 22, 2000), email: patrick.lynch@yale.edu; also available in print: Lynch, P. J.; Horton, S. *Web Style Guide: Basic Design Principles for Creating Web Sites;* Yale University Press: New Haven, CT, 1999.
7. Liu, D.; Walter, L. J.; Brooks, D. W. *J. Chem. Educ.* **1998,** *75,* 123–125.
8. The 1997 AP Chemistry Examination, The College Board: New York, NY. Reprinted with Permission of the Educational Testing Service and the College Entrance Examination Board.