Physical Chemistry On-Line: Maximizing Your Potential

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Abstract

The Physical Chemistry On-Line (PCOL) consortium has developed and conducted a series of short-term projects for use in the physical chemistry curriculum. The projects involve faculty and students from geographically dispersed institutions, are short in duration (~4-6 weeks), and use e-mail and the World Wide Web for communication and information distribution. They are designed to enhance physical chemistry at colleges and universities which may have limited resources available for physical chemistry, by offering an alternate pedagogical approach. This paper will highlight the motivations of the participants, outline the specific projects used to date, and provide some evaluation of the pedagogical effectiveness of the approach.

Outline

I. Motivation

Recently, there has been significant interest in developing improved physical chemistry curricula (Moore & Schwenz, 1992; Worthy, 1992). Motivation has largely been driven by the belief that the current "traditional" curriculum does not reflect the current practice of physical chemistry. Additionally, student interest in physical chemistry, one of the traditional gateway courses into the profession, is low. In response to these concerns, there has been increasing interest given to the development of new experiments for the physical chemistry laboratory, those that employ more sophisticated, modern experimental techniques (Schwenz & Moore, 1993). Additionally, some have pursued the development of "activity" based instructional methods (Zielinski, 1995).

Despite these important educational advances, physical chemistry instructors who wish to be innovative often find themselves isolated in small departments that cannot provide the equipment necessary to offer recently developed laboratory curricula, nor the institutional or collegial support necessary to support innovative classroom practice. An obvious solution to this problem, given current communication technology, is to use the Internet to link geographically dispersed physical chemistry classrooms as the vehicle by which to transform and improve educational practices.

Although much has been written on the potential benefits of using the Internet as a tool to educate chemists, there are few examples of studies that assess the impact of the technology on chemical education, or provide actual working examples of Internet applications in the chemistry classroom (Towns et. al., 1997). At the college level, the work has too often been parochial, with the most common application being examples of web based syllabi. In these cases the technology is aimed at enhancing a single lecture class by providing a common and convenient location for educational resources, and is innovative only in that a unique delivery method is used for the material. This is all the more disappointing given the exceptional technology that has been developed to provide interactive web material, and to enhance the ability to communicate chemical ideas on-line (Tissue, 1995; Rezpa et. al., 1994; Casher et. al.; 1995). Some exceptions are being highlighted in this and other recent CONFCHEM online conferences.

From a traditional standpoint, the trend in current use of Internet technology is not surprising given the standard practices used in most classrooms. Generally it is true that communication technology has not been adapted to the classroom. For example, movies, radio, tape recorders, television, and video tape machines, technologies that appeared as much as 80 years ago in some cases, are applied very little in today's classroom, and then, when applied they are generally used to display images of a lecture, or at best, to show lecture demonstrations. (Swift and Zielinski, 1997). It is no wonder that the Internet has been applied mainly to distribute syllabi and course notes.

What is needed is an innovative way to provide substantial curriculum content in a context that is both stimulating to students and pedagogically sound. This curriculum should also be constructed to take advantage of the asynchronous instructional potential of electronic interactions. The faculty participants in the PCOL consortium are endeavoring to provide this content by adapting strategies- including cooperative/collaborative learning, case studies, and discovery based learning, to the Internet. We believe that the Internet is well suited to these types of learning strategies (Long et. al., 1996a).

II. Projects to date

Over the past three years we (see Table 1) developed and tested five modules (see Table 2) in a pilot project which linked several geographically dispersed physical chemistry classes for short term projects.

Table 1: PCOL curriculum developers

Faculty member	Institution, location
Theresa Julia Zielinski	Monmouth University, West Long Branch, NJ
George Long	Indiana University of Pennsylvania, Indiana, PA
George Shalhoub	La Salle University, Philadelphia, PA

Roland Stout	University of North Carolina, Pembroke, NC*
Gabriela Weaver	University of Colorado at Denver, Denver, CO
Deborah Sauder	Hood College, Frederick, MD
Marcy Hamby Towns	Ball State University, Muncie, IN

* through 5/99.

An on-line physical chemistry activity is an interactive exploration of chemical concepts by groups of students from three or more institutions, a community. During an on-line event students obtain materials over the Internet. One faculty member serves as facilitator for the community. The facilitator's role is to provide guided inquiry directions as the students work their way through the module. Students in the learning community work in groups at their local campus and then share results with all other groups or with partner groups on the other campuses. Data and written results are shared by e-mail or by posting on a web page or both. Peer review among students is included in the on-line work. Sharing and pooling data occurs with experimentally based modules. The time span for an on-line activity is four to six weeks, running parallel with normal classes and laboratories but usually substituting for some experiments and/or lecture material.

PCOL activities use the ability to collaborate via the Internet to help students learn chemical principles. The sphere of collaboration of individual students is broadened beyond their own institutions, giving each participating student a greater perspective on physical chemistry, and a better appreciation for the challenges inherent in understanding the field. In addition, the projects are designed by a team of faculty, and thus have contributions from several faculty perspectives as well. Therefore, the project is multi-dimensionally collaborative in that it focuses on collaboration among students on one campus, student groups between campuses, and faculty between campuses. The outcome is that together we can do more than any one faculty member can do alone and our students get more collegial interaction than is possible in any one individual, small, physical chemistry class.

One philosophical principle guiding the development of the on-line projects is the concept of a learning community (Cross, 1998; Cooper and Boyd, 1995). The learning community provides an organizational framework useful for encouraging group learning and discovery. We have chosen to use this model to develop a more interactive, student-centered perspective from which to use the Internet. Support for building such communities comes from three areas: empirical research on learning outcomes (Chickering & Gamson, 1987; Springer, Stanne, & Donovan, 1998), research on the personal and intellectual development of college students (Perry, 1970; King and Magolda, 1996, Belenky et al. 1986), and research on motivation and cognition (Brooks, 1999). This body of diverse research supports the notion that engaging students in actively seeking and building knowledge is the key to learning. We believe that getting students actively involved in asking and responding to questions is critically important.

The structures and pedagogical content of the five PCOL projects developed and implemented so far are outlined below. More substantial information, including digests of the on-line interactions are available for some of the projects are available at the WWW addresses linked below.

Table 2: PCOL modules implemented to date

Module title	Topic	Date
"How Hot is That Flame?"	Determination of adiabatic flame temperatures	Fall '96 Fall '98 Spring '99
"It's a Gas!"	Non-ideal equations of state and non-linear	Fall '96

	curve fitting	
"The Structure and Spectroscopy of Iodine"	Classic experiment to determine potential energy surface parameters from visible absorption spectra	Spring '97
"Doc. Z's Bungee Jumping Emporium"	Thermodynamic and experimental investigation of polymer elasticity, with applications	Fall '97
"Shady Laser Corp"	Classic experiment to measure the absorption spectra of conjugated dyes, and develop several models and correlate absorption characteristics with dye structure	Spring '98 Spring '99

Project 1. "How Hot is That Flame?"

principle author: Theresa Julia Zielinski
on-line facilitator: Theresa Julia Zielinski

This project was the trial run for the first on-line chemistry course, sponsored by the CCCE (Long, 1996). Three classes, with a total of 20 students participated. Designating one faculty member to facilitate the on-line work of the students was found to be successful. A major difficulty was student access to computer terminals. During the Fall 1998 semester this project ran again with a group of seven participating colleges and 50 physical chemistry students.

The project began with students accessing a web page which included an essay written by a chemist idly watching a fire and wondering how hot the flame was. The page went on to outline some factors that one might take into account in order to answer this question, provided some thermodynamic parameters, and asked students to perform a preliminary calculation to determine the flame temperature.

In the on-line implementation, the variety of answers generated by student groups on their first attempt to calculate a flame temperature provided strong motivation for students to write about the details of their calculations in a professional manner as they attempted to reconcile the results of their multiple calculations of "the same" phenomena. The facilitator then provided encouragement to extend the calculation, including some more realistic considerations.

In the Fall 1998 implementation, student groups were asked to repeat their calculations for a variety of hydrocarbon fuels, share their results and draw some conclusions about the temperatures expected in the adiabatic limit for flames generated by combustion of different fuels. A full assessment of the activity is being prepared. Preliminary results will be presented at the American Chemical Society meeting in San Francisco.

The third implementation of the Flame project occurred in the Spring '99, with three schools participating and 19 students. For this activity, the web page was redesigned and the materials organized and delivered with web links. Even with 19 students and three faculty participants, students were not frequent contributors to the discussion of determining the flame temperature. We discovered that students wanted to treat the material as a single session homework problem, post their results and move on the the next topic. The facilitator, Zielinski, attributed this student response to the steady diet of passive learning that occurs in most college classrooms. One participating group, from Utica College, posted most of the messages and showed the enthusiasm for online work observed in other PCOL activities. Two participating students showed exceptional commitment to the project, and learned how to do web presentations so they could publish their project on the project's web page. Their results can be found at http://www.monmouth.edu/~tzielins/FlameS99/endofproject.htm, along with other outcomes from this activity.

Project 2. "It's a Gas!"

principle author: Theresa Julia Zielinski
on-line facilitator: Theresa Julia Zielinski

This project, during the Fall semester of 1996, involved physical chemistry students from four different institutions (Sauder et. al., 1997). Students in the project read a play conveying a conversation between two chemists who were discussing gas behavior and non-linear curve fitting. Students were assigned a set of gas data (P vs. n) at fixed (V,T) and asked to determine the best fit parameters (as determined by the standard deviations) if the data was described by the ideal gas law, the van der Waals or the Redlich-Kwong equations. They were then asked to use the "f test" to decide which equation best described the data. This was not a trivial task, as the students (and we) discovered.

Network brownouts and a hurricane, which took the North Carollina participants off-line for a week, revealed the hazards of technology used for delocalized instruction. The strengths of the project were the interaction between students, the use of Mathcad and modern technology, and the experience of solving an authentic problem, not an exercise. The project suffered from technological difficulties, insufficient interaction among the students, and student inability to extract the clues in the play and formulate questions to solve an ill-defined problem. The suggestions for improvements focused on facilitating interaction between students, clarifying tasks and goals etc. (Towns et. al., 1997). Both the resources provided to participants and an archive of the on-line discussion for this project are available at url: http://www.iup.edu/~grlong/realgas.htm

Project 3. The Structure and Spectroscopy of Iodine.

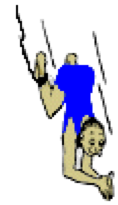
principle authors: George Long & Deborah Sauder
on-line facilitator: Deborah Sauder

The format of the on-line project during the Spring of 1997 changed dramatically in response to our evaluation of the Fall activity (Stout et. al., 1997). The web pages became more important for directing the discussion. Step-wise interaction kept the students focused, and firmer local course requirements increased student participation in the intercollegiate discussions. Both the resources available to the students and an archive of the on-line discussion are available on the web at url: http://www.iup.edu/~grlong/i1fac.htm

A full exposition of the concepts and depth of learning possible with technology can be found in a recent article prepared by the consortium (Long, et al. 1999). This project began with some very simple questions about visible absorption, asked students to measure absorption spectra, and convey their experimental procedures and results coherently to their colleagues via e-mail. It then and led them through several Mathcad documents designed to establish the fundamental models and outline the calculations which allowed the student chemists to glimpse both the ground and excited potential energy surfaces from the absorption spectra of diatomic iodine. Revised versions of the Mathcad documents used in this module, and descriptions of the documents are available at the JCE Internet site. (Zielinski, 1998).

Project 4. "Thermodynamics of Bungee Jumping"

Principle authors: Theresa Julia Zielinski
George Long, & Deborah Sauder
On-line facilitator: Deborah Sauder



In the Fall of 1997 we conducted the most successful project to date. It focused on the thermodynamic properties of polymers. Although the Iodine project was successful in leading students through a structured learning process, we wanted to employ a less didactic approach better suited to the asynchronous nature of electronic communication and more likely to encourage a mature student analysis of the problem. The bungee project was successful in meeting both of these goals.

Initially, students used a listserv to respond to general questions designed to bring out their prior knowledge of polymers and guide them towards a laboratory investigation of polymer properties. The conversational tone of the opening discussion helped students get comfortable communicating with their intercollegiate partners on-line. None of the participating classes had considered polymers before the project started, so students were referred to several texts to gather background information on polymer thermodynamics (Grosberg and Khokhlov, 1997; Bovey and Winslow, 1979), in addition to being asked to search the World Wide Web for reliable information.

Students were then referred to Williams' "Thermodynamic Properties of Elastomers" (Williams, 1993) and asked to use the resources available at their institutions to design laboratory experiments to determine the stress-strain relationship of rubber bands at a variety of temperatures. They posted their results to their class home pages. A guided discussion, facilitated by a PCOL faculty member, had students consider trends in the data sets and draw conclusions. Students then applied their insights to real bungee jumping, performing calculations to provide virtual technical advice (appropriate thickness and length of cords) to the bungee jumping emporium owner, Doc Z.

A particularly successful aspect of this project was the last - students wrote papers on topics related to the thermodynamic properties of polymers, such as the development of artificial muscle or the Challenger disaster. Papers were peer reviewed by partner groups at different institutions. Revised papers were posted to the web and a student-faculty discussion of the papers occurred on the listserv.

This student centered activity, included at the suggestion of PCOL member Roland Stout, combined and implemented proven instructional strategies such as collaborative learning and writing in the discipline in an on-line environment. Participating faculty felt that the paper writing, and peer review in particular, helped students to develop the teamwork and communication skills necessary for the workplace.

Copies of the materials used by students, an archive of the on-line discussion and some sample student papers can be accessed through url: http://www.iup.edu/~grlong/bungee.htm

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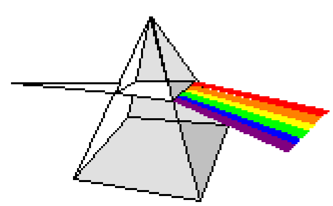
Project 5. "Shady Laser Corporation"

principle author: George M. Shalhoub
on-line facilitator: George M. Shalhoub



In this modification of the classic conjugated dyes experiment, students were asked to imagine they were members of the Shady Laser Corp. research team. They were to examine the absorption spectra of a number of conjugated dyes and use their data to provide a recommendation as to a chemical structure which would provide a laser dye with a specific set of optical characteristics. The diversity of dyes, solvent systems and concentrations employed by the various student groups provided a nice enhancement of this activity vis-à-vis its use in an isolated classroom. Students were asked to agree on parameters for both 1D and 2D particle in a box models for describing the absorption characteristics of the dyes. They also used the molecular modeling software available on their campuses to model the dye behavior. Students at some campuses used Spartan to generate structures for the dye molecules and then taught themselves how to use Chime and created models that others could rotate and view at their home campuses.

The materials distributed to students for this project are available at url: http://wey238ab.ch.iup.edu/pcol/dyeproj2.htm. Some sample student work is available at http://www.niagara.edu/chemistry/studproj/pchem/

III. Pedagogical evaluation

A strength of the PCOL initiative is the interactive, mutual encouragement of the faculty during the development and execution of the curricular modules. The group draws on the multiple technical expertise of the participants. These span from thermodynamics through kinetics and on to spectroscopy and computational chemistry. In addition, disciplinary-specific pedagogical experiences have been shared, providing the collegial support necessary to support innovative classroom practice.

Another especially important aspect of the collaboration is the collegial interaction required from students participating in the projects. Requiring collegial interaction develops student's ability to work with others while they construct understanding of a chemical concept. Group work within one class is complemented by intercollegiate group activities that draw on multiple student competencies. These interactive skills will be required of future chemists, as we all know from experiences with CHEMCONF and other on-line professional activities.

Assessment of our pilot projects revealed that students, like their faculty counterparts engaged in professional on-line activities, are enthusiastic about using the Internet and world wide web for learning chemical concepts, *once they get started*. One thing we have learned from PCOL is that the anonymity of on-line communication offers no advantage compared to the exposure of the classroom setting, when it comes to engaging students in chemistry projects. The engagement needs to come from the curricular materials and facilitator guidance offered in the module. One learns best when one is engaged in an activity. As teachers we are always looking for the hook with which we can engage students in the creative process that leads to enhanced learning. This is the power of the undergraduate research experience. Therefore, an important goal of PCOL's efforts is to provide curricular frameworks for real problems, so that students become actively engaged with the project. The active engagement is what enhances learning and empowers students to think of themselves as independent learners. Context based teaching helps students to learn and retain concepts and to envision the use of those concepts in new situations. It empowers students and helps imprint life-long learning habits.

One might ask if some content is sacrificed by infusing the on-line modules into the curriculum. Research in chemical education shows that there is too much content in the curriculum for any one physical chemistry semester. It is time to streamline and modernize. This consortium of faculty think that by reducing content we will allow students time to develop critical thinking skills and life-long learning habits. Ultimately, this will permit them to learn more and learn it more effectively throughout their careers.

Using technology; the web specifically, and proven pedagogy; especially active learning and collaborative group work, will provide students with an opportunity to develop life-long skills to a greater extent than is possible when content is delivered in lecture format, which is too often passively received and therefore easily forgotten. We expect, based on our own experiences, that the content learned using web modules is more deeply rooted in student concept structures. This more than compensates for the content not covered.

IV. The future

The PCOL consortium members agree that the "Thermodynamics of Bungee Jumping" project was our most successful to date. We therefore anticipate continuing to modify our existing projects to maximize their value to us and to our students. Ideally, every PCOL project will encourage student and faculty collaboration by

*** establishing a real world context for the project

*** including both experimental and theoretical components in an open-ended format rich with student centered activities that model the scientific process

*** requiring students to collaborate in the writing of a report or paper to increase engagement with the topic and provide the application of concepts in a new situation

*** facilitating students' constructive peer reviews of each others' efforts.

We are also actively developing new curricular modules with these goals in mind. In addition to topics commonly covered in a physical chemistry course, we will include topics relevant to the current practice of physical chemistry. We anticipate taking continual advantage of improving technologies and advances in software to encourage students to confront challenging chemical questions and savor the satisfaction of a successfully answering them.

We invite any group of collaborating faculty to use the materials identified in this document in their classrooms, as they see fit. Our experiences would lead us to recommend that three to five faculty participate in any one project, with perhaps a total of 20-25 students. This is a manageable size for one facilitator, and requires enough active participation to keep all the students engaged, and provides a variety of student and faculty perspectives to keep things lively.

Individual faculty with large classes can also use the materials for intracollegiate cooperative learning activities in a single chemistry course. We would be interested in having additional review of our materials and assessment of them by many colleagues. Contact Marcy Towns for assessment materials.

We have all benefited tremendously from the formation of the PCOL learning community. Using the Internet to link geographically dispersed physical chemistry classrooms has provided us the vehicle to transform and improve our educational practices. Our best projects have engaged our students, improved their communication skills, and helped them learn some physical chemistry.

However, for those of you considering the approach, we do not want to underestimate the labor required. In addition to the PCOL members who have acted as project authors, on-line facilitators, and internal reviewers of documents, we want to highlight the fundamental importance of PCOL's web master and primary server manager, George Long at Indiana University of Pennsylvania. We certainly could not conducted any of these projects without him. In addition, we need to recognize the institutional contributions from IUP, the University of Colorado at Denver, and Monmouth University for the allocation of web space and support of listservs.

We endeavor to maximize our effectiveness as teachers and our students' success in physical chemistry by continuing to improve our on-line pedagogy and continuing to take advantage of the rapid technical advances we all experience everyday. We invite you to try the approach, too.

V. Participating faculty, e-mail addresses, and affiliations.

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