DUE-CCLI Award #125076

"The Reactor Lab: Chemical Reactor Simulations for Active Learning"

FINAL REPORT

Introduction

This project was initiated in March 2002 and completed in February 2005 at the end of a one-year no-cost extension. The Reactor Lab allows students to explore the behavior of the chemical reactors as if they were doing experiments in a laboratory, with the advantages of low cost, safety, and the ability to explore conditions not achievable in a lab. This active participation in learning helps students learn about and understand the behavior of chemical reactors. The software framework of the Lab is field-independent and can be extended to other fields.

The Reactor Lab will continue to be developed and also will provide a transition to a full-scale development project which is currently under consideration by NSF. The full-scale development project, PureWaterLab, will incorporate the software framework of The Reactor Lab, will have a broader scope, and will expand our collaborations with the NSF/SRC Engineering Research Center for Environmentally Benign Semiconductor Manufacturing.

Summary of goals and accomplishments

This section lists the goals of the project, as stated in the project proposal, and summarizes the accomplishments. More extensive descriptions of the accomplishments are provided in sections below.

Goal: "To enable collaborative learning by integrating the lab simulation prototype with the Internet."

Much of the effort in the project went into accomplishing this goal. Prior to the project, the Lab was distributed via the web as a single download of a standalone desktop application, with no way for a user to update the software other than going back to the web site and downloading a new version. Now, the user downloads only the core software from the web site. The core software is a desktop application which has Internet communication capabilities. Lab modules are downloaded from a server and can be used on- or off-line. The software is updated automatically whenever the user is on-line. A "Conference Room" allows uses to post messages and "talk" with other users who are on-line at the same time. English, Spanish and Portuguese versions of the Lab have been downloaded by students and instructors from 97 countries.

Goal: "To enhance student ability to analyze and design chemical reactors by providing simulations of a wide range of chemical reactions and reactors."

The Lab provides 24 modules comprised of a total of 32 simulations. There are a variety of levels of sophistication so that students can explore and understand simplified reactors before progressing to more complex and realistic systems. Four new modules were developed during the current project, and these are described below. Feedback from students shows that the Lab increases their interest in and helps their understanding chemical reaction engineering.

Goal: "To enable students and instructors to create their own laboratory simulation modules by adding a lab construction kit to an existing lab simulation prototype."

A prototype lab construction kit was developed and is described below. Accomplishing this goal was determined to require much more work than anticipated, and our plans for this goal were altered, as described below.

Goal: "To communicate the lessons learned in this project and distribute the software framework, which is field-independent, to faculty in other fields of science and engineering."

The Lab will be distributed with the major textbook in the field of chemical reaction engineering. A research paper was published on the theory related to one of the new modules developed. The research was presented at national meetings of the ASEE and NSF. The Lab is listed at a variety of web sites including NEEDS, MERLOT, and chemical engineering-specific sites. The core software has been downloaded from the web site more than 8700 times during the three years of the project. The software framework of the Lab will be redesigned and rewritten in the PureWaterLab project with the aim toward distribution of this framework to other educators.

Integration with the Internet

Prior to this project, The Reactor Lab was a standalone desktop application. Now the Lab is an "Internet application" or "Internet app," which is also referred to as a "rich client." The core software of the Lab is obtained by download from the Lab's website at ReactorLab.net as before, however the size of the file has been reduced substantially. Versions of the core software for Windows, Mac and Linux operating systems are available. The student starts the desktop Lab application and can choose to work on- or off-line, i.e., with or without an Internet connection to ReactorLab.net. The Directory window of the Lab is shown in Fig. 1.

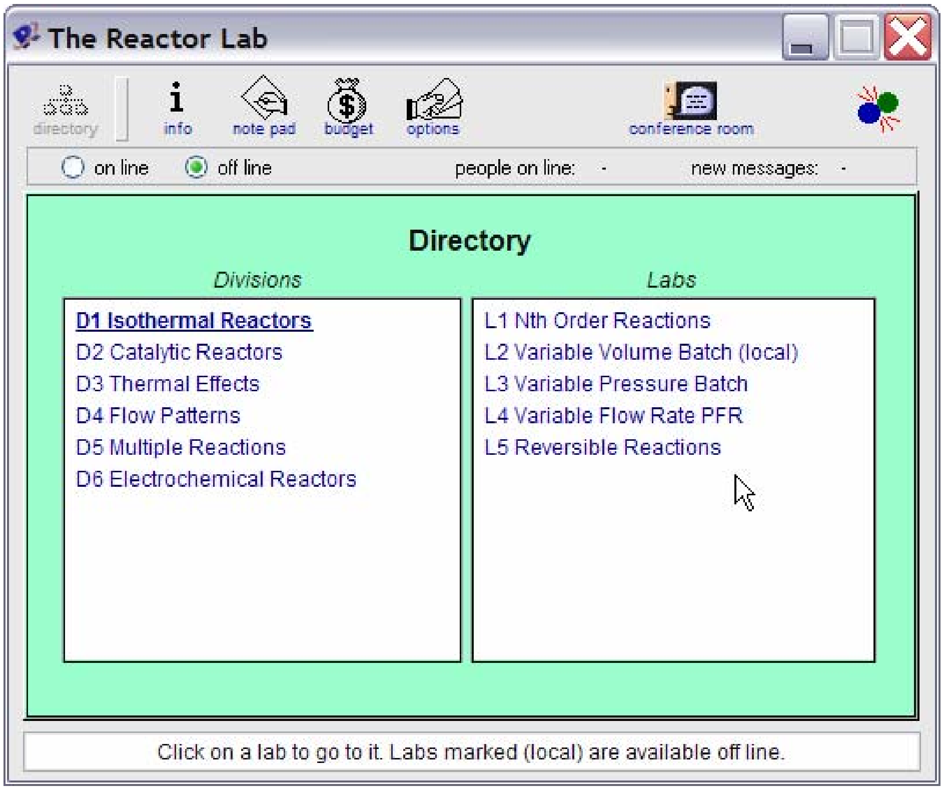

Fig. 1. Lab Directory. Note information about the cursor location in field at bottom.

The Lab is easy to use because of the consistent design of its interface and because information about each object in a window is displayed in a field at the bottom of the window as the cursor passes over the object. Context-specific information is available by clicking the info button in each window.

When the student clicks on a module name, the module opens. Lab modules marked (local) are resident on the local computer, or client, and can be run when the client is on- or off-line. When the client is on-line and the student clicks on a non-local module in the Directory, the software downloads the module from the web server and opens it. The downloaded module is also saved to the client's disk as a local lab for use later when off-line. When the client is on-line and a local module is selected, the software checks the server to see if the local lab is the current version. If not, the current version is downloaded and the local lab is updated. All files except the core desktop application are cross-platform so that only one version of each file is posted on the server.

Fig. 2 shows one of the interactive modules. This module allows a student to investigate reactions occurring in parallel where one product, D, is desirable and the other, U, is undesirable. Students can experiment and determine conditions under which production of D is favor. They can change the values of the kinetic parameters in the box on the left, and click the three valves to open and close them as the simulation runs. The simulation runs six-times faster than real time, so the simulation in Fig. 2 has been running 5 min and 27 s of simulation time but less than 1 min of real time. The plot on the right scrolls continuously and all of the graphics and the curves in the plot are color-coded.

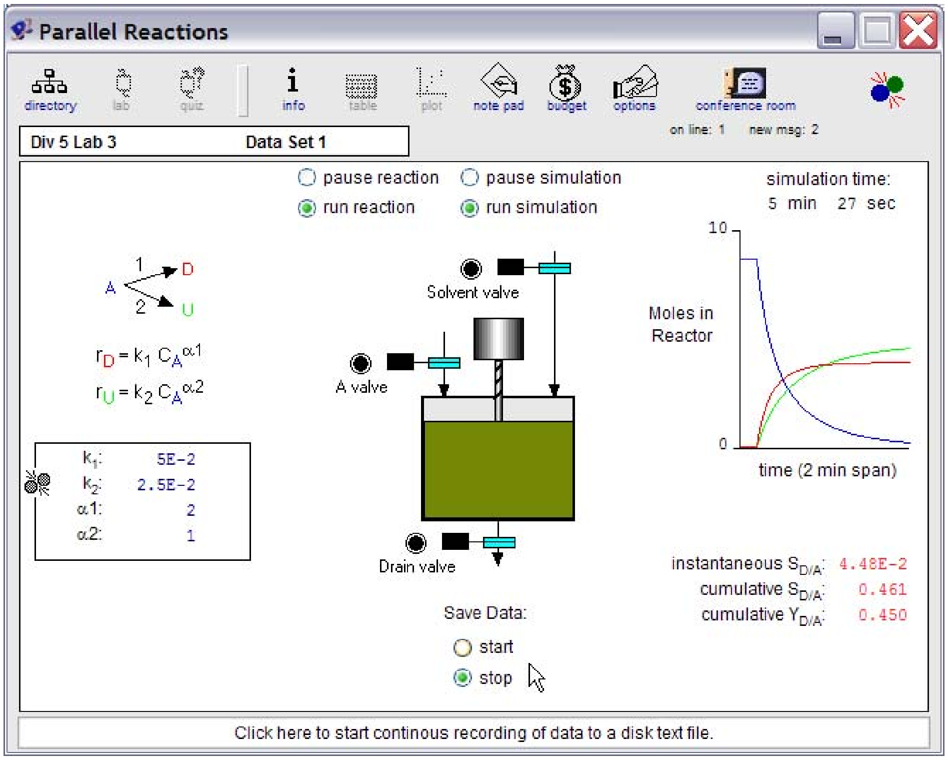

Fig. 2. Parallel reactions in a batch reactor. Best viewed on color computer screen.

The interactive simulations in the Lab allow students to actively manipulate and explore the material they are learning about in a very dynamic and visual way. This provides a powerful enhancement to their understanding and retention of concepts.

A major addition to the Lab which was enabled by integration with the Internet is the Conference Room. Students can post messages in the Conference Room and can talk to each other when more that one student is using the lab and on-line, i.e., "instant message." Students enjoy this feature very much and the PI has found it very useful for conducting "office hours" from his home the night before an assignment is due.

Fig. 3 shows a conversation in the Conference Room between the PI (Rich), a postdoctoral fellow (Nihat) at the University of Michigan working with Professor H. Scott Fogler on his Interactive Computer Modules (ICMs), and an undergraduate student (asli) at the Yildiz Technical University in Turkey who was using the Lab in a class assignment. The postdoc also was from Turkey and the two continued their conversation in Turkish. Note the last item on the first line of each message which shows the time difference from Greenwich Mean Time of the person posting the message. Three different zones are shown: -800 (San Diego), -500 (Ann Arbor), and +200 (Istanbul).

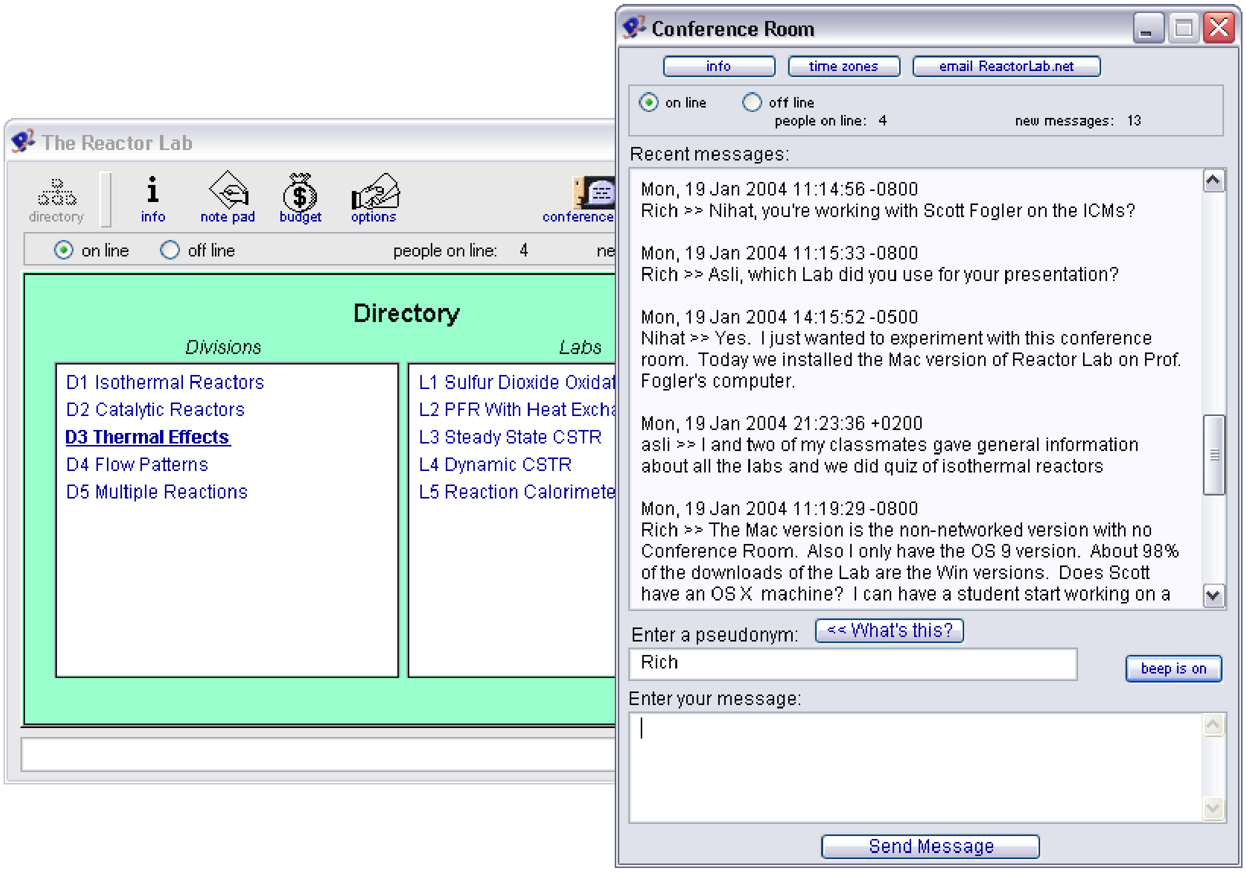

Fig. 3. Conference Room showing 3-person conversation across 10 time zones (messages posted to a public message board with unrestricted access).

Most simultaneous conversations have occurred when the PI's students were working on a homework assignment. They exchanged greetings and asked for and gave help to each other. When the PI was also on-line, productive "virtual office hours" were conducted. The PI also conducted an on-line conversation with a student at the University of Michigan who thought he discovered a software bug while working on a homework assignment but had actually "discovered" that negative-order reactions in stirred reactors can exhibit multiple steady states.

Because module files are downloaded in response to the same hypertext transport protocol (HTTP) requests that web browsers use to get web pages, such requests are logged the same way all web servers log requests. Thus the patterns of usage from individual Internet protocol (IP) addresses or IP zones can be obtained by analysis of server logs.

In addition to the server logs, new capabilities for logging student use of the Lab were implemented. The lab modules entered and times spent in each module are also recorded in a log file that is separate from the raw server log and much easier to analyze.

The types of modules available include:

(a) Single data point per experiment, where "data point" includes values of several output values at one time during a transient experiment or at the output of a continuous steady state process.

(b) Time series of data points in one experiment on a transient or dynamic process conducted to a final time.

(c) Continuous output during a continuous dynamic simulation. (e.g., Fig. 2)

(d) Simulations in which results are displayed on the screen but not recorded by the program for saving to disk. Plots of results are provided in the lab window.

In lab types (a)-(c), student can save data to disk in one of several formats. Data saved to disk can be imported into program of student's choice, such as Excel and Matlab, for plotting and analysis. A simple plotting function is provided in the Lab itself for data saved to disk in the current session in order to compare results of a series of experiments to make sure good results have been obtained.

Several types of assignments can be given to students. In qualitative assignments, students are asked to perform experiments and write a comparison of behavior between two reactor types or, for example, comment on the sensitivity of self-sustained oscillations in the Dynamic CSTR to changes in parameter values.

Automatically scored quizzes can be assigned in many of the modules. Each student is given a unique set of unknowns upon each entry into a quiz. The student has to decide what experiments to perform in order to get data that can be analyzed in order to obtain the unknown input values. When they supply their answer, the program tells them whether or not it is correct. Correct answers are awarded virtual $, which are recorded in the Lab's Budget. Students are required to turn in copies of their data and analysis work, in addition to a code-authenticated copy of the Budget.

In longer assignments, one can ask students to determine the complex kinetics of the catalytic methanol synthesis reaction, or use the SO_2 oxidation reactor to design and optimize a multi-stage reactor-heat exchanger system.

New Modules

Four new modules were to be developed in the project. The proposed list was: reaction calorimeter (topic - chemical reaction safety), photo-catalytic water purification (topic - photochemical reactions), H_2-O_2 fuel cell (topic - electrochemical reactions), and batch fermenter (topic - biological reactions). The first three of these planned modules were developed but another module, a reactor network simulator, was developed in place of the fermenter. The new modules which were developed in the project are described below.

<u>Reaction Calorimeter</u>

A simulation of a type of an accelerating rate calorimeter was developed. New compounds are tested in calorimeters like this in order to determine the level of hazards associated with the compound. The lab module is shown in Figs. 4 and 5.

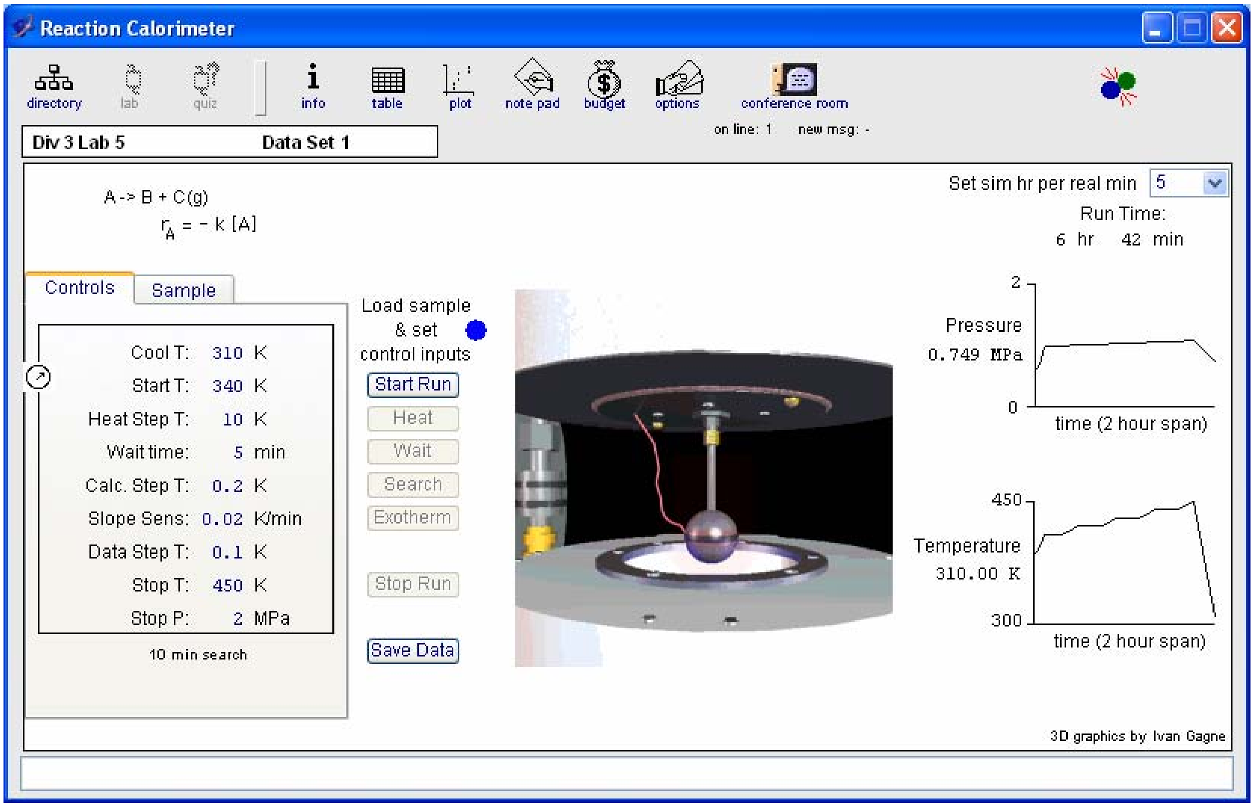

Fig. 4. Reaction Calorimeter prior to start of a new experimental run.

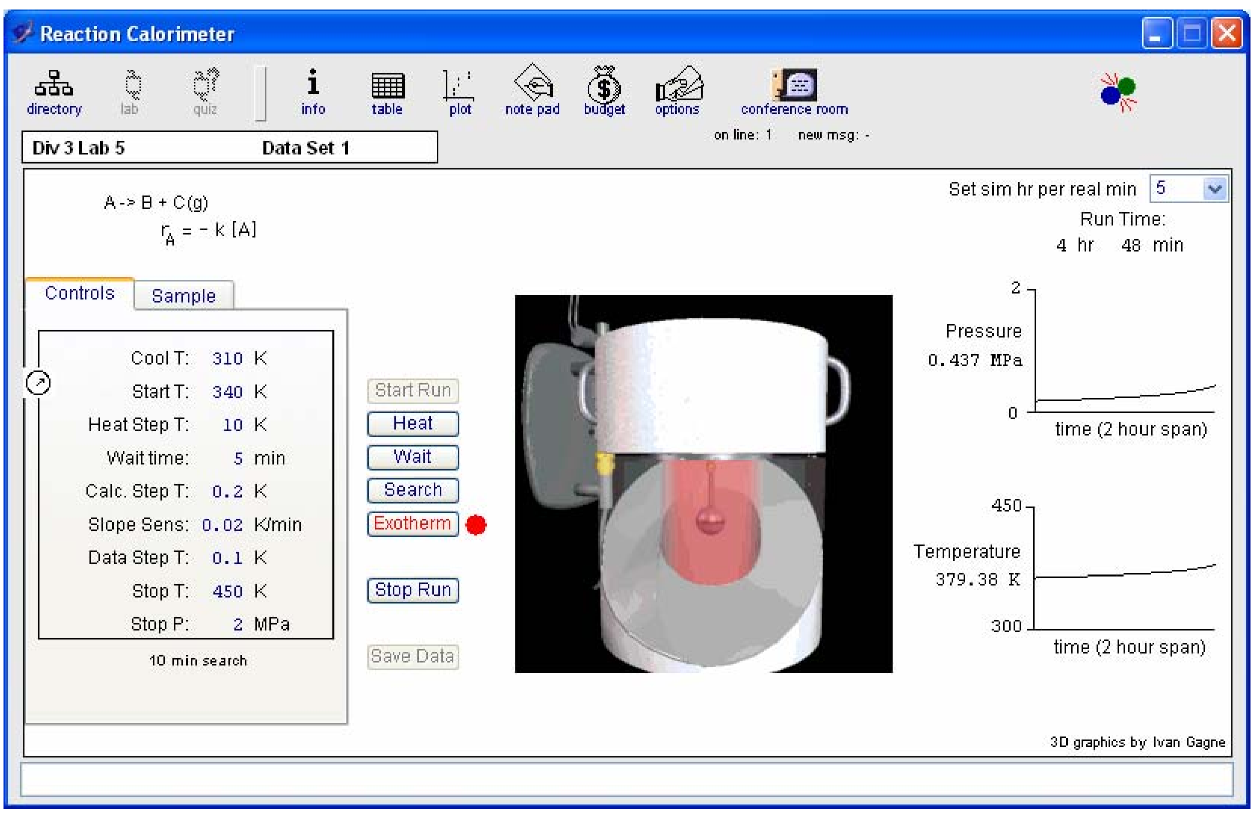

Fig. 5. Calorimeter is cut away and a reddening "fog" illustrates sample heating.

Actual experiments with these units typically last a complete work day. The software simulation allows day-long experiments to be run in minutes. Note the button in the top-right corner of the white area of Fig. 5 which allows the user to select the relationship between the time of the simulated experiment and the time at which the simulation actually runs.

The animated 3-D graphics were developed by an undergraduate student employed by the project. We hope to be able to add such exciting graphics to more modules in the future, since they increase student interest as well as being more realistic.

Photocatalytic Filter

As a result of our collaborations with the NSF/SRC Engineering Research Center for Environmentally Benign Semiconductor Manufacturing, we developed a new lab module for photocatalytic oxidation of pollutants in water. Fig. 6 shows the new lab.

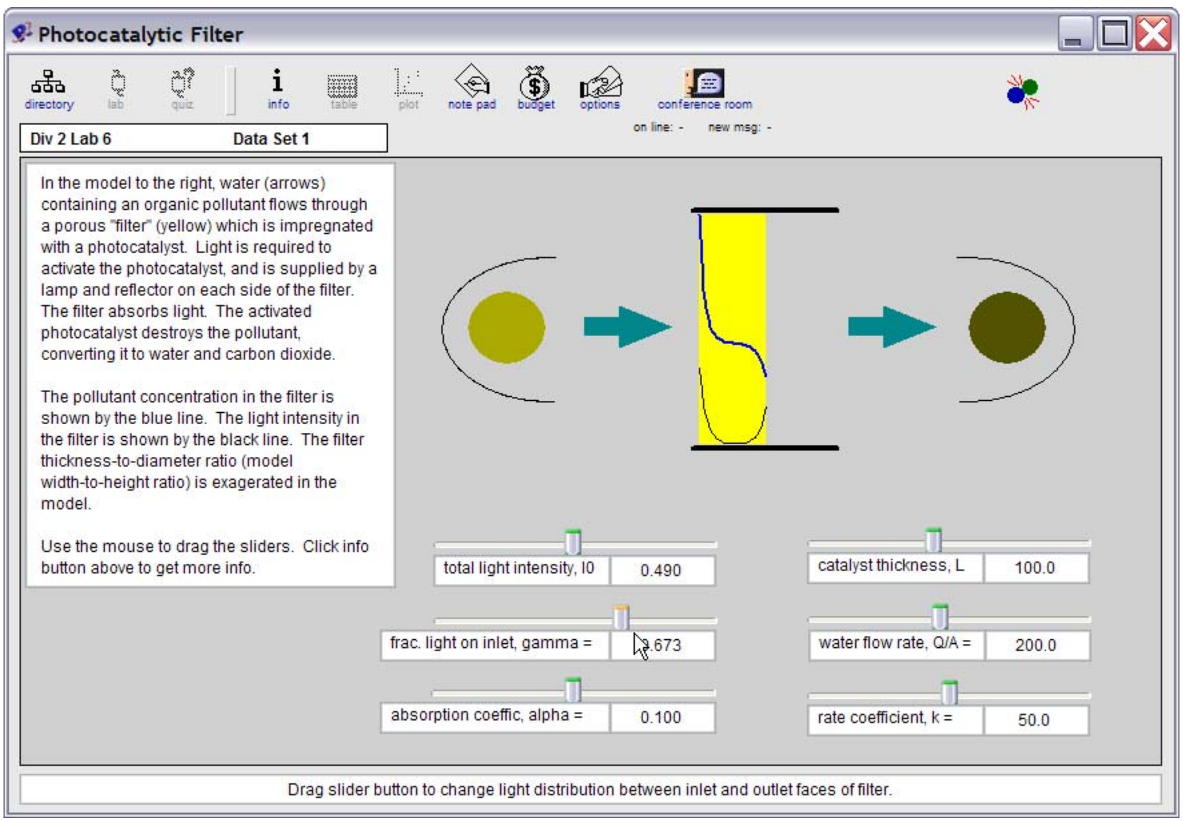

Fig. 6. Photocatalytic filter for purification of water.

The circles and parabolas on the left and right represent UV lamps and reflectors. The rectangle in the center is a permeable filter material that entraps titania photocatalyst particles. The arrows represent water flow through the filter, and the thickness of the arrows change as the student drags the slider control which varies the water flow rate. The top curved line in the filter shows the concentration of a pollutant species in the water. The bottom curved line shows the light intensity profile within the filter. As the student drags the slider controls, the display is continuously updated: lamp color and intensity, water arrow thickness, and the two curves.

In the process of developing the equations for this module, the PI wrote and published a paper in a major research journal on the theory involved: R. K. Herz, "Intrinsic kinetics of first-order reactions in photocatalytic membranes and layers," *Chemical Engineering Journal*, vol. 99, no. 3, pp. 237-245 (2004). This is an example of how undergraduate education and research can be synergistic.

Fuel Cell

A simulation of a hydrogen-oxygen fuel cell was developed and is shown in Fig. 7. The simulation model was based on one reported in the recent research literature. That model was developed from theoretical considerations and measurements of a real fuel cell.

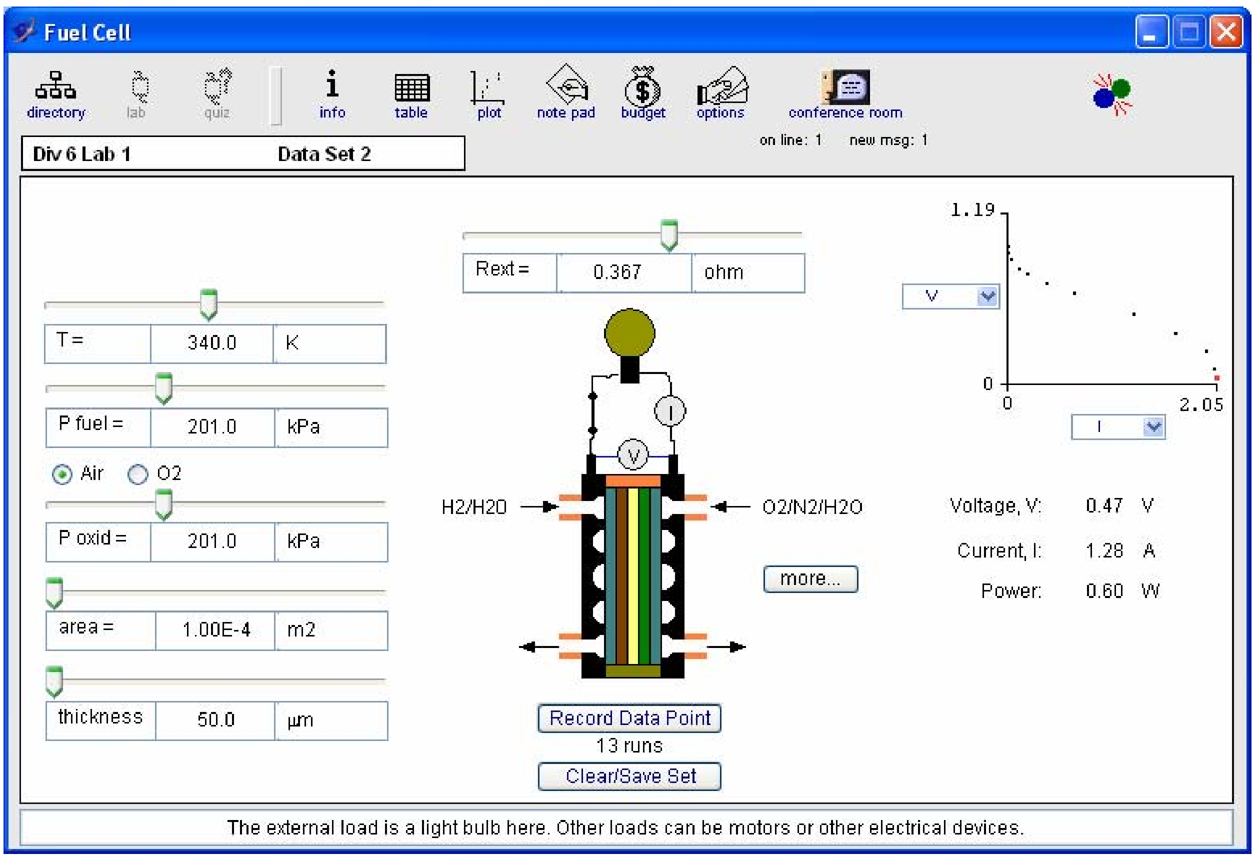

Fig. 7. Main window of fuel cell module.

The user can slide the cursor over the parts of the fuel cell cross-section shown and see a description of each part in the text field a the bottom of the window. Clicking the "more..." button to the left of the cross-section opens a window with more graphics and descriptions, as shown in Fig. 8.

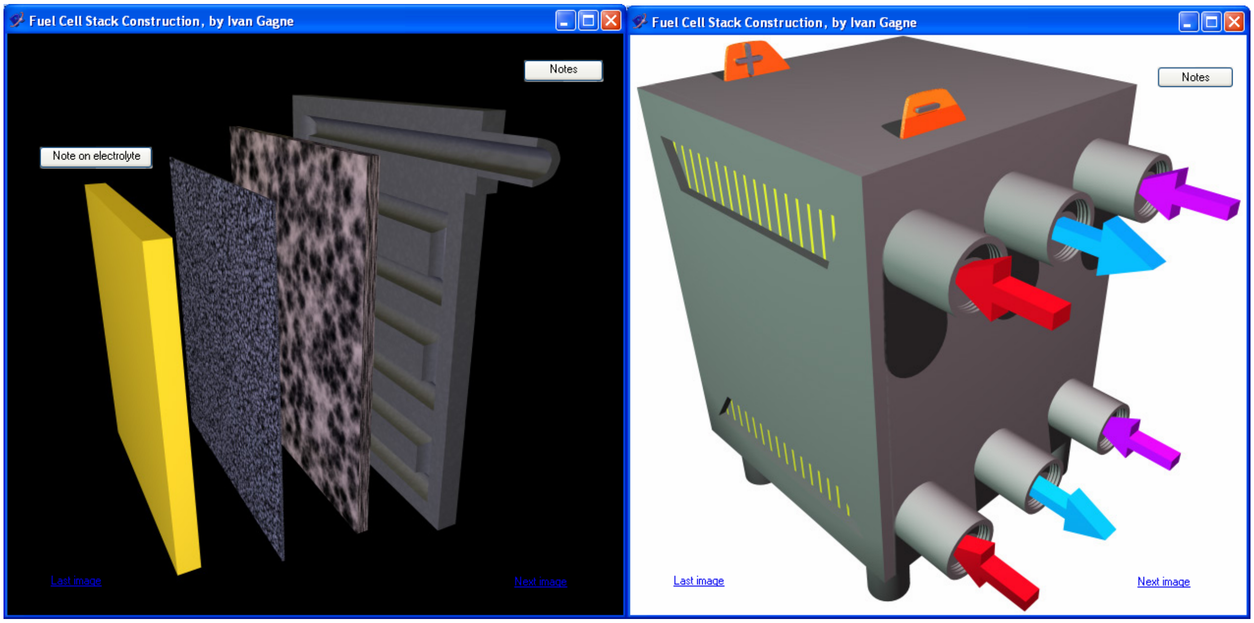

Fig. 8. Additional graphics showing fuel cell construction.

Reactor Network Simulator

This module allows students to design, construct and operate their own networks of chemical reactors. Fig. 9 shows the reactor network module.

Students can run a pre-assembled system or can start from a blank flow sheet (main white area on left of Fig. 9). To build a new system, the student selects process units on the "unit palette" on the right and places them on the flow sheet. Units are then connected with pipes. The chemical species present in each fluid stream and the sizes and operational parameters of each component can be set. The simulation in Fig. 9 shows a system with partial stream recycle. Clicking the Run button runs the simulation and values of key parameters change in the display. In future versions, students will be able to turn valves and make other changes while the simulation is running, as they can in some of the other current modules.

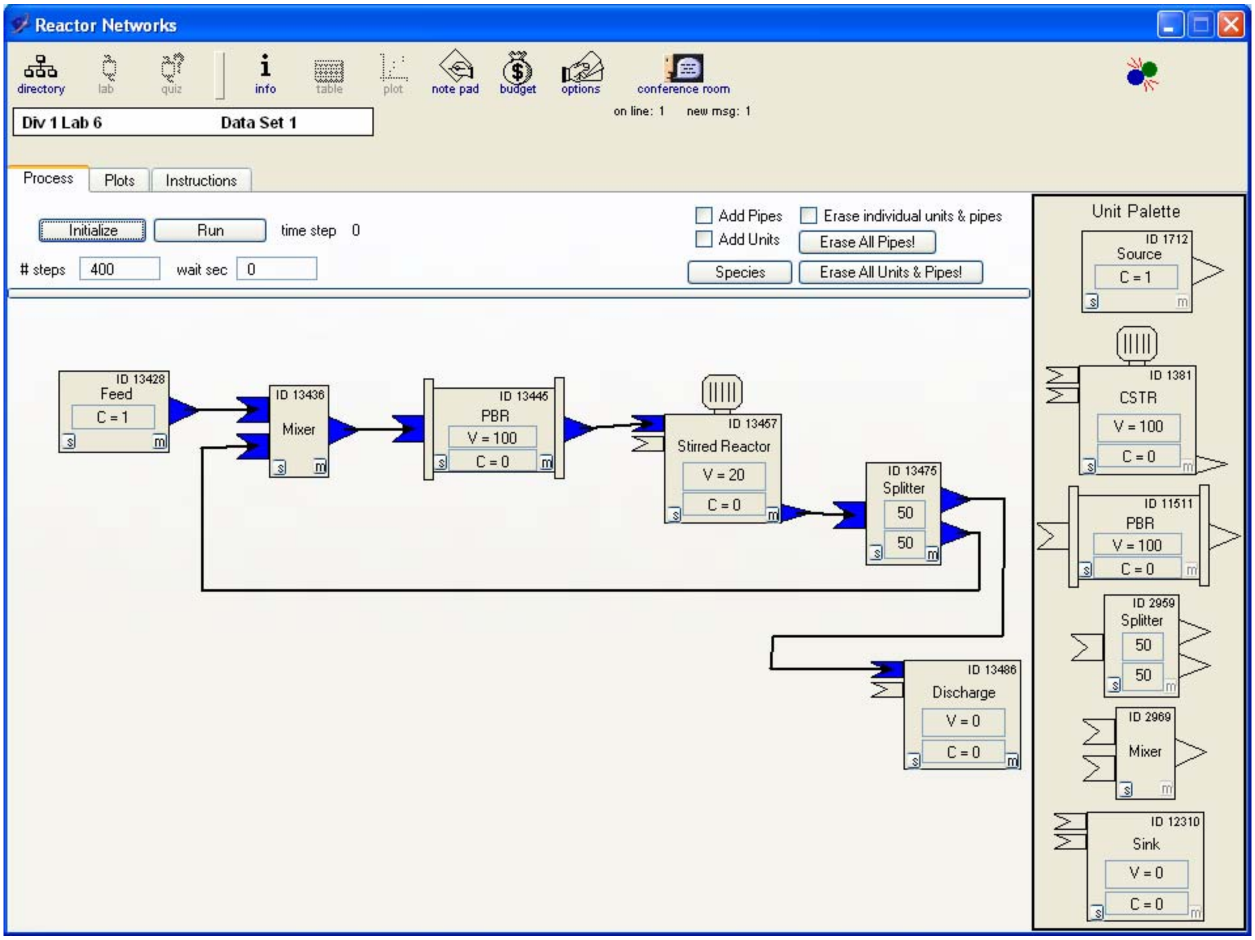

Fig. 9. Reactor network simulator. Process shown with recycle loop.

Fig. 10 shows a plot of the results of a simulation of this system in which an compound dissolved in water, species A, is released from the Feed unit for 10 time steps and is then shut off as the flow of water continues (top plot, blue line in Fig. 10). The bottom plot of species A in the Stirred Reactor shows how the pulse of A fed to the process propagates around the recycle loop until it eventually reacts and elutes away.

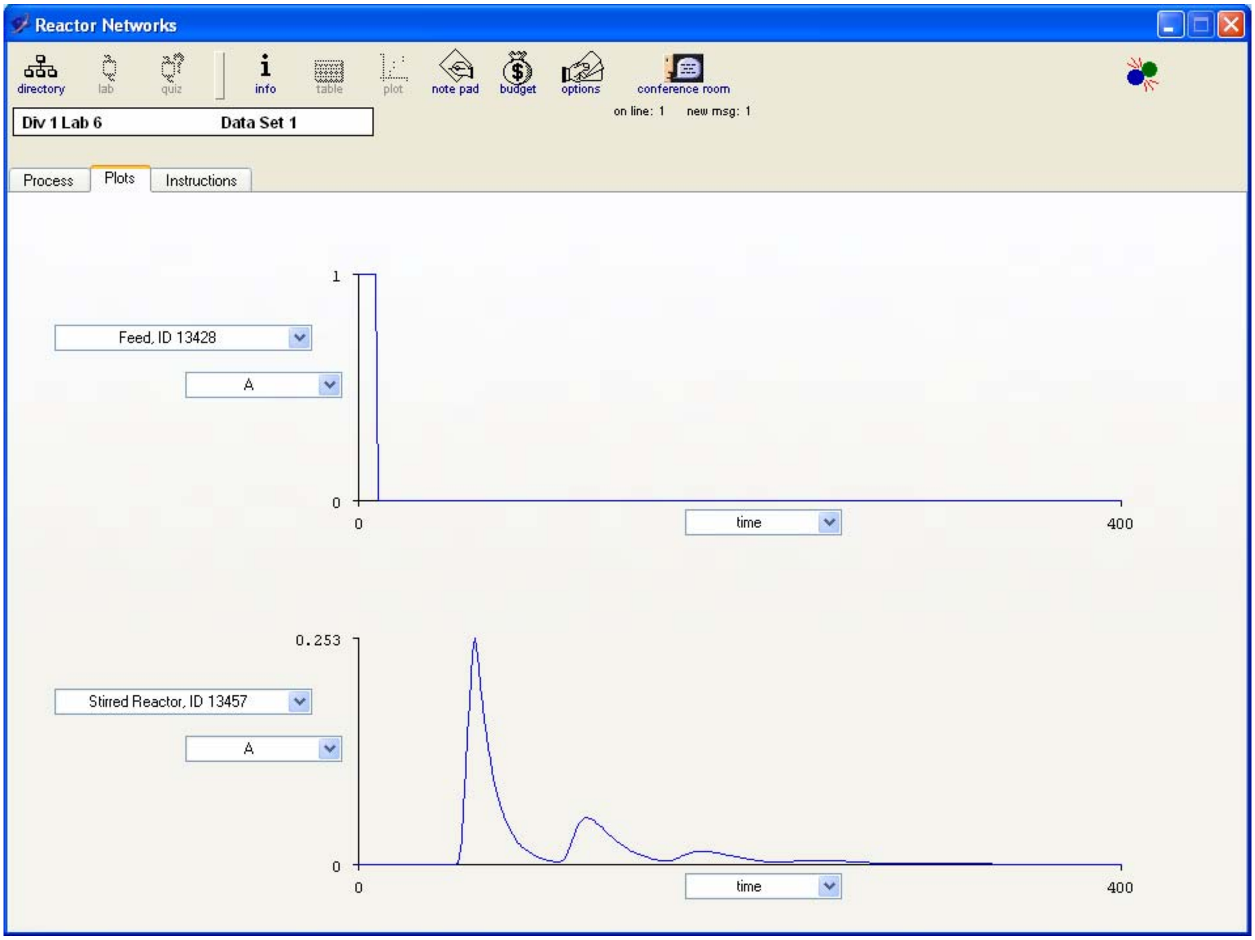

Fig. 10. Dynamic response of Stirred Reactor (Fig. 9) to pulse input to system.

One of the novel features of this simulator, when compared with other dynamic process simulators, is that all messages sent between units are composed in eXtensible Markup Language (XML) and include the sender and the recipient addresses. This will allow remote units to be included in a student's process. A remote unit can be located anywhere on the Internet and can perform its internal computations on any type of computer in any computer language.

Initial tests were made on a two-unit process, with one unit located on a computer in San Diego and one unit located on a server in Houston. An average messaging time of 0.18 s per time step was obtained for 4^{th}-order Runge-Kutta integration of the process models via TCP/IP socket connections at the high Internet traffic time of mid-day and mid-week.

Vendors can make simulations of commercial units available and hide proprietary code from view if desired. Students will have fun collaborating with others at their own school or students in distant schools and will get experience with working in distributed teams. The instant messaging system that is operative in The Reactor Lab will let students converse as they design the system, run the system, and analyze its performance.

Lab Construction Kit

Developing new modules can take substantial time. One goal of the project was to provide a "lab construction kit" which would allow others to develop new modules as well as speed our own development process.

Our current method of developing a new lab module is to copy a similar module, rename it, and then edit it to make the new module. This method works reasonable well for us but would be difficult for others to apply. Even for us, some elements are overlooked and must be fixed by trial and error. We think that a form-based method may have advantages for development of new modules.

The Lab was designed to have a consistent interface across modules to help students quickly adapt to using new modules. This consistency of design helps to make a form-based construction kit possible. Also helping to make a construction kit a possibility is that all modules have similar types of variables (input, computed input, output) and the need for similar objects and functions (graphic of process, information, plot, table, etc.).

Fig. 11 shows one panel of the prototype construction kit that was developed in the project. When the screenshot was taken, the user was in the process of entering a new input variable. In other panels, other aspects of a module such as the visual layout and graphic components are defined. Finally, a button is clicked and a new module is generated.

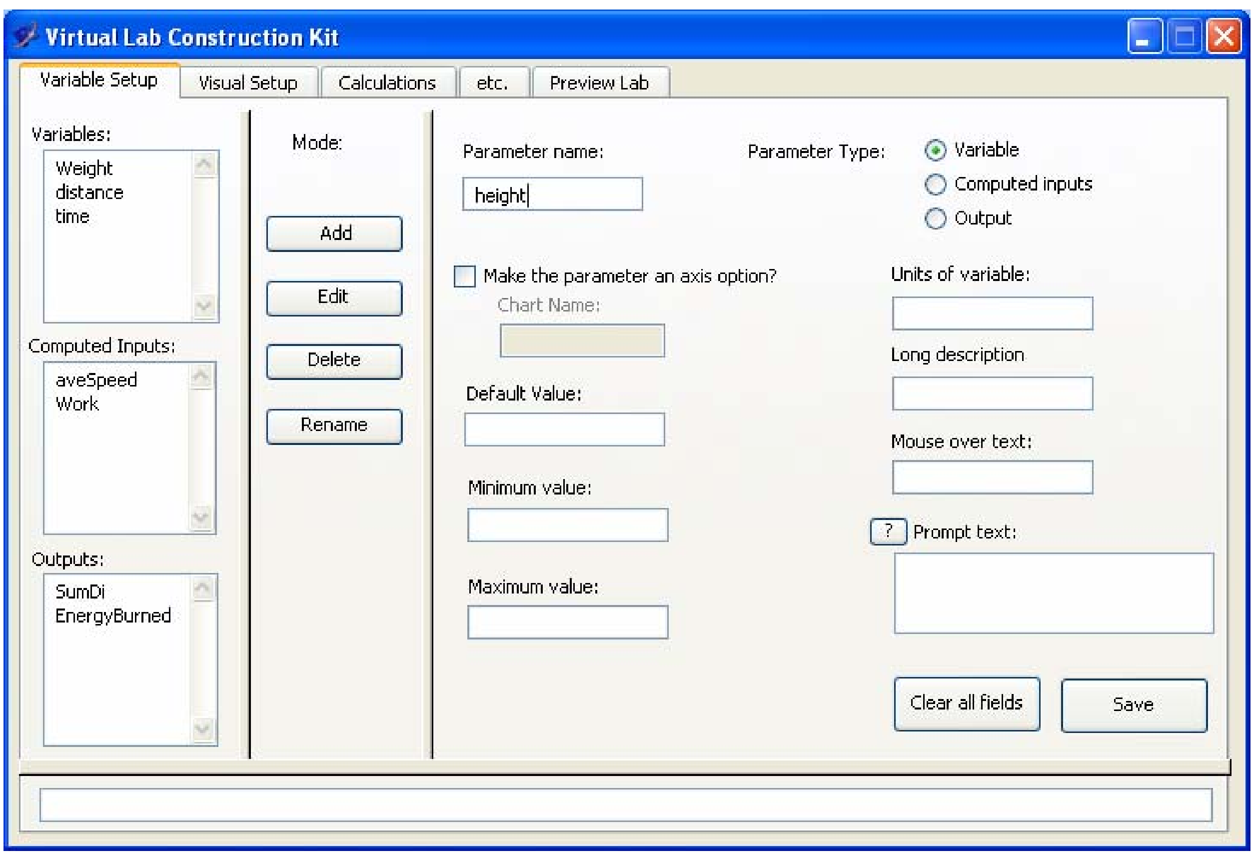

Fig. 11. Defining a new input variable in the prototype lab construction kit.

Fig. 12 shows a lab module generated by the current construction kit. Obviously, the construction kit is still in a preliminary stage of development.

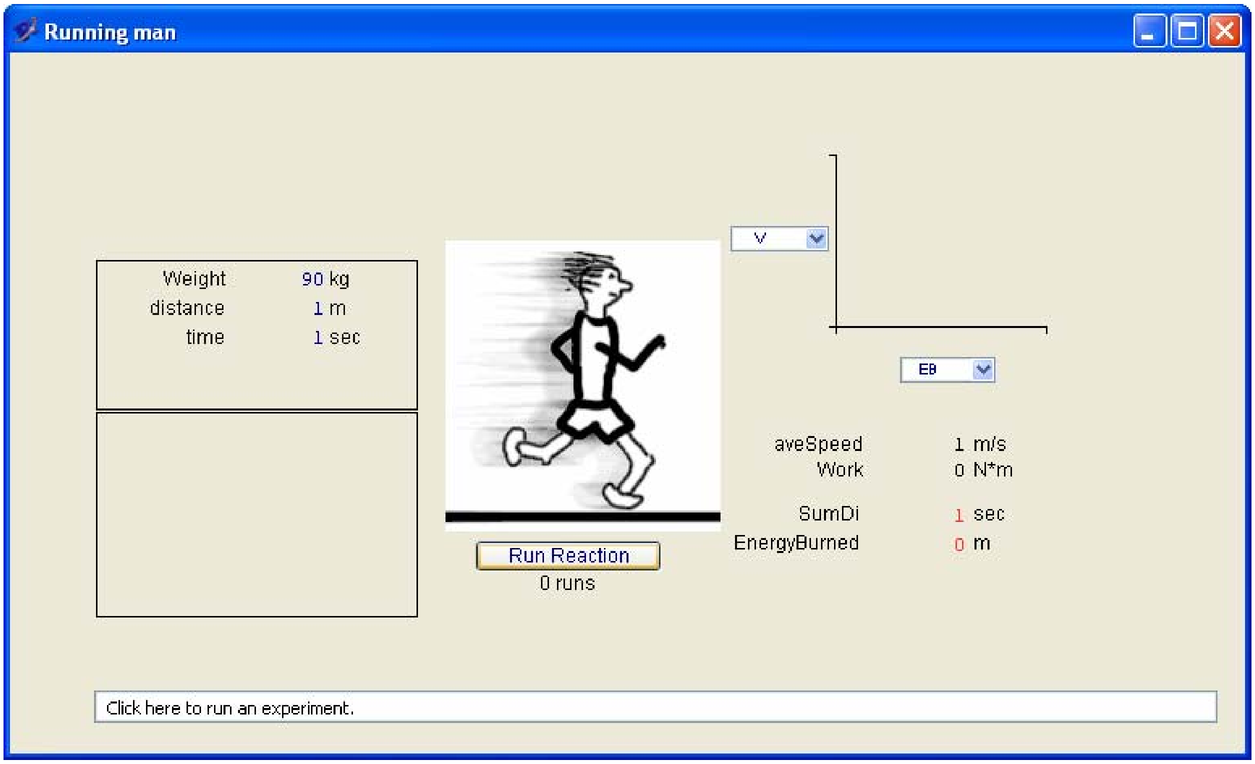

Fig. 12. Module generated by current prototype lab construction kit.

In future work in our full-scale PureWaterLab project, we plan to conduct a redesign and rewrite of the software structure of the Lab. The new structure will be designed to assist in the development of a lab construction kit.

Distribution and Use in Courses

The Reactor Lab will be distributed starting in 2005 on the CD-ROM included with the 4th edition of the major textbook in the field of chemical reaction engineering, Elements of Chemical Reaction Engineering by H. S. Fogler and published by Prentice-Hall. A research paper was published in a major journal which developed the theory behind of one of the modules in the lab, as described below. Presentations were made at national meetings of the American Society of Engineering Education and NSF CCLI grantees, and at the annual review of the NSF/SRC Engineering Research Center for Environmentally Benign Semiconductor Manufacturing.

The Lab is distributed free of charge at the web site www.reactorlab.net. From the start of the project in March 2002 through its end in February 2005, there have been 5282 English, 2496 Spanish, and 958 Portuguese-version downloads.

We have heard from instructors and students using the Lab in courses in Bolivia, Brazil, Chile, Columbia, Italy, Mexico, The Netherlands, South Africa, Spain, Taiwan, and Turkey, as well as in the U.S. Professor Scott Fogler, author of the major textbook in the field, used the Lab for homework in his course in Winter 2004. Here is email from a student at Yildiz Technical University in Istanbul, Turkey:

> *Date: Thu, 15 Jan 2004 13:27:57 -0500 (EST)*
> *From: aslihan <aslihanayse@yahoo.ca>*
> *Subject: I really appreciate all your help*
> *To: "Richard K. Herz" <herz@ucsd.edu>*
>
> *Mr. Herz;*
> *Our presentation have been so succesfully that it was clapped by everybody, including our instructor. Actually we have not understand the labs 100 percent. However we think that it will be usefull for next year.*
> *In order to prevent misunderstanding I want to axplain that our instructor had had no idea about The Reactor Lab untill I found this program through "google". Our instructor's name is Prof. Semra ÖZKAN. Her email is: ozkans@yildiz.edu.tr*
> *That is very kind of you to give us time and information about the labs. I really appreciate all your help.*
> *Yours sincerely,*
> *Aslýhan Ayþe GÜRBÜZ*

The Lab is listed at a variety of web sites including NEEDS, MERLOT, and chemical engineering-specific sites. The Lab software has been downloaded from the web site more than 8700 times during the three years of the project. The software framework of the Lab will be redesigned and rewritten in the PureWaterLab project with the aim toward distribution of this framework to other educators.

Translation into Other Languages

The Spanish-language version of the Lab was released near the end of the first year of the project. The translation of the text displayed by the lab was carried out by volunteers: Luis Arteaga and Tania Paredes of the Universidad Mayor de San Simón in Cochabamba, Bolivia. The Spanish version was preceded by the Portuguese version which was released earlier and produced with the help of volunteers at a university in Brazil.

The Spanish version is downloaded at roughly 50% of the rate of the English version and the Portuguese version at somewhat less than 20% of the rate of the English version. These figures illustrate the need to consider translation when designing new software. Unfortunately, the structure of the Reactor Lab was not designed to facilitate translation. We have learned our lesson and our future projects will be designed from the start to facilitate translation into other languages.

Evaluation

Students learn from two main differences from textbooks and exercises: (1) they get to interact with a model of the process, and (2) they have to design experiments and generate data themselves that will lead to solving a problem.

Some students appear shocked to encounter an assignment so different from a textbook problem. After running an experiment, they stare at the screen, then after a while ask me, "what do I do?" They ask this, not because they don't understand how to use the software, but because they are only comfortable working the usual textbook problems where a necessary and sufficient set of input is given them and a single quantitative answer is asked of them.

The vast majority of my students have liked using the lab in the course. They have said that it helps them get a better qualitative feel for the material.

Some have made good suggestions which have been implemented, for example, make info text printable and copy-able, and make the last data point in the thumbnail plot a different size/color to distinguish it from previous points.

Much can be learned by watching students perform assignments. One lesson is that they value program responsiveness and speed of operation over graphical richness because their number one objective is to get the assignment done fast.

The PI has used the Lab successfully in his courses, and student evaluations for two years are listed in Appendices at the bottom of this document. Their comments are interesting to read. They felt the Lab was useful in helping them gain an understanding of the material. Several suggestions were made for improvement of the Lab. The main suggestions were to speed up shutdown of the software when quitting and to add more theoretical explanations of the material.

Conclusion

This project successfully produced a resource for students to actively participate in learning about chemical reactors. The goals of the project were met and we eagerly anticipate work on our proposed full-scale development project in order to continue the advancements made.

APPENDIX 1 - Course Evaluations, Winter 2004

Results of an anonymous questionnaire given at end of CENG 113 Chemical Reaction Engineering course taught by PI in Winter Quarter 2004 at the University of California, San Diego. 19 sheets were turned in. Not every student answered every question. Questions and responses transcribed from originals.

HEADING:

CENG 113 - Winter 2004

QUESTION 1:

Briefly comment on things you like about using the Reactor Lab in this course.

QUESTION 1 RESPONSE:

They go well with what we were learning. The lab seems somewhat structured like the class.

It is almost like getting hands on lab experience by teaching the methods that would be used to perform such experiments.

I can see what happens without getting hurt because the reactor blew up.

It's quite easy to use.

One of (probably the) most helpful thing learning-wise in the course - running reactions, doing the calculations to figure out variables... many times multiple times over to kind of drill that process into my head.

It gives real world applications. Lets me see how the equations look when applied to a reactor.

The conference room, how it keeps log of previous chats.

Seemed to have much learning opportunity. Help visualize the course better.

It was good but had long loading and closing times. I liked the data output.

Since chem engs don't have very many lab classes, using the Reactor Lab gives a "hands on" component to the course and lets you get a feel for how changing parameters influences performance.

Helps us to understand the equations we're learning.

The conference room.

It's awesome to be able to see how a reaction would go without having to solve a system of ugly equations.

Sometimes we could check our homework with it.

I like watching the experiment take place. In liked that the data plotted itself.

It forced one to manipulate and understand the equations and workings of the models until I got it right. Kind of a forced learning with "real" reactors.

It does computations for you.

QUESTION 2:

Briefly comment on any difficulties you had using the Reactor Lab.

QUESTION 2 RESPONSES:

In some of the labs, more info should be provided stating relationships between variables and what the lab is trying to teach.

At my girl friend's house it was very difficult to get online because she went through a proxy. The weird thing is that I do too but had no trouble.

$Money$ I know it is an imaginary feature but it sucks at the beginning because my confidence level went down the drain when I lost $59,000 just for playing around the first time. I think you should add a button to turn off the budget.

If formulas/equation is provided, that would be great. So that won't get lost when doing the quiz.

Solving them.

Sometimes things just didn't seem to work right as far as solving for variables. Such as I'd have eta, do the calculations 100% correcxt for k, and still not get the right value.

The directions were always very vague and I wasted a lot of time guessing at what I was supposed to be doing.

Getting started with the very first homework.

Sometimes it seemed even though you have a correct theoretical answer when applying this answer you still get a wrong answer.

Some of the descriptions of the lab parameters should be shown more directly like D4L2, the pulse amount was kind of hidden.

None. The one lab that was giving me trouble (the adiabatic PFR) has since been fixed.

It's annoying to have to re-click on the Divisions to bring up a working lab list. For some reason, the labs don't load the first time.

Trying to find initial conditions that I liked, I ended up with no money in my Budget.

Not really much of any besides a couple bugs that have already been fixed.

There was one lab (can't remember which) that we just couldn't get the correct Ea or k on. It didn't make sense - we figured it was an error of Reactor Lab and moved on.

I had problems with re-entering quizzes.

Sometimes not sure what supposed to be done.

It was a pain sometimes, no difficulties that weren't forcing me to learn though.

It's complicated to navigate through some of the reactors, especially the complicated ones.

QUESTION 3:

Please provide one or two suggestions for new labs or improvement in operation of current lab.

QUESTION 3 RESPONSES:

Detail the chemistry more so that the lab window has more meaning.

Some sort of tutorial would be great to explain the different methods and just what needs to be done. Maybe just a list of relevant equations for each lab would work too.

On/off button for budget.

An improvement: change the way a user can increase/decrease inputs, i.e., cA0, V, v0, etc. Maybe an arrow (up and down arrow figures), instead of opening the window.

Maybe some way to contain all the different windows? Avoiding desktop clutter.

Have a manual/tutorial that describes step-by-step what to do for a certain type of CRE problem. (i.e., adiabatic CSTR, want T and X, do... (give procedure))

Could you make it so that when you close the program that both the conference window and main window closes. The beep is really annoying.

A user interface more like LabView controls, so instead of clicking a box we can click an arrow.

Efficiency. Load up/close could be long. Used more computer resources that I thought.

More hints in the info. Sometimes you just don't know what is going on.

I like the conference room. If there is a way to get that back up, it would be good.

Change the conference room to more of a message board type organized a little better.

Give brief scenario before lab.

Maybe a few more examples at clear cut quizzes.

Put more info in the "i" tab to explain the reaction, what it does, and how the quiz may be solved. Currently, it's a little confusing.

QUESTION 4:

Overall, do you think using the Reactor Lab in this course helped your interest in and understanding of the material?

QUESTION 4 RESPONSES:

It definitely helped my understanding of hysteresis loops in a CSTR. Otherwise I understood everything already.

Yes. I liked it a lot.

Yes. [total of 4 plain "Yes"]

Not really. I was already sufficiently interested in the book material; the Reactor Lab actually just frustrated me.

Yes it did. It was one way to show it related to real-life examples (sort of).

Yes. It showed reactor results nicely.

It was frustrating at times, but yes.

Yes, the "money" incentive makes it like a game and makes you proud to get a working run.

Yes, another way to see and understand things.

Yes, very much so.

Sort of. Not really. It was easier to plot than just having to manually plot tables in Excel.

No.

Yes it did and I began to use it toward the end on some of the homework to help me check my answer.

Yes it did. I liked the first few assignments, but then it got hard and confusing.

APPENDIX 2 - Course Evaluations, Winter 2003

Results of anonymous questionnaire given at end of CENG 113 Chemical Reaction Engineering course taught by PI in Winter Quarter 2003 at the University of California, San Diego. 24 sheets were turned in. Not every student answered every question. Questions and responses transcribed from originals.

HEADING:

Reactor Lab evaluation

UCSD CENG 113 - Winter Quarter 2003 - March 21, 2003

The Reactor Lab is partially funded by a grant from the National Science Foundation. This evaluation will help development of the Lab.

QUESTION 1:

What do you think the best mix of homework problems would be, with choices among problems in Fogler text, use of the Reactor Lab, other problems you suggest?

QUESTION 1 RESPONSES:

The mix given this quarter was good.

Homework was fine. Maybe a little more discussion on how Reactor Lab works - why we get wrong answer, etc.

I like re-working Fogler's examples in Reactor Lab because you know if you're doing it right.

I liked how the Reactor Lab complimented the text.

Fogler text and Reactor Lab and maybe some research problems.

Reactor Lab and some that are guided from lecture. Fogler problems are not too helpful.

1 Reactor Lab, 1 Fogler [not readable word(s)] -> solve for answer using PolyMath. One design where you set up and think of set up, not calculation.

A few problems from Fogler with 1 or 2 problems from the Reactor Lab would be best. Too many Reactor Lab quizzes is very time consuming.

Good mix.

I would choose mostly Fogler (maybe 2/3) and 1/3 Reactor Lab.

I felt the homework requiring us to do the lab quizzes was nice.

I liked the mix of Fogler problems and Reactor Lab quizzes. I find the quizzes enhance the text in a way that brings concept to use.

A mixture of Fogler text and Reactor Lab problems were very helpful to understand the different types of problems.

Doing things in Fogler, and then the Reactor Lab is most beneficial.

I thought the balance of Fogler to Reactor Lab quizzes was good. Except the last chapter needed more quizzes.

I didn't really like the Fogler problems. I thought the Reactor Lab quizzes were more representative of this class.

Maybe something like 75% Fogler, 25% Reactor Lab.

CSTR, PFR, PBR catalyst problems and glucose oxidation. Since it helps with the senior lab designing.

Fogler and Reactor Lab are both helpful.

After 4th week (maybe third) about half Reactor Lab and half Fogler is very helpful.

The way it is currently divided is fine.

Problems from Fogler text using Reactor Lab.

QUESTION 2:

What are the two <u>worst</u> things about the Lab?

QUESTION 2 RESPONSES:

It's frustrating that the Lab can be so precise at times. You could be off one or two numbers and spend hours thinking you've done the problem incorrectly. Also quitting the program takes too long.

The randomness generated in numbers. The correction for standard state "sometimes."

All the pop up things when trying to close.

Can't save the plot unless use data and put it in Excel. Can't make own titles for files that you save.

It takes a long time to close.

The random error it has and sometimes it requires a lot of analysis to solve problems.

Sometimes it seems strategy can work for one correct value and not another value.

The data given in the quiz is sometimes hard to manipulate (i.e., it's difficult to get reasonable conversion). You can't copy pieces of columns straight from the data tables (i.e., highlight and copy).

Can't see how close/far you are from answer if it's wrong.

There are errors in the program such as negative conversion [RH: this is not an error in program, only appear to get negative conversion near zero conversion due to random error deliberately added introduced into readings]. It does not teach anything about the reactions, just gives values.

The retrieval of data in the text files is cumbersome.

I don't like the error involved in some of the labs (D2L2). I had it crash my computer before, don't like that.

Menus keep popping up like crazy when exiting the program.

After changing a certain value in the variable box, if you press 'enter' too many times, it'll run the reaction more than once.

When I enter in the same data twice, the results are not always the same [RH: this is due to random error deliberately added introduced into readings and stated in lab info]

The screens are not very maneuverable and are small, but I do like how you can see the inside of the reactor and how it works.

Don't like the fact that it was hard to shut down - it would pop up another window to close. Could use more visual effects.

That you can't maximize the screen - I like to work with larger pictures.

When plotting things such as k, if k was too small, simulation would yield a negative value sometimes by random scattering. Scattering at times seemd to be based on set value instead of a percentage.

The data irregularly in the catalyst problems since it fluctuates quite oddly. Saving the files seems odd... move convenient if saved files were in Excel format.

There are too many windows that popup when saving data and closing the lab.

Doing the procedure correctly and still not being able to solve a quiz. Trying to figure out how to get back into a quiz.

The quizzes don't always work and that was frustrating.

Even though problem is approached correct, if you don't have the correct numerical number you answer it wrong and it's frustrating.

QUESTION 3:

What are the two best things about the Lab?

QUESTION 3 RESPONSES:

Very user friendly and easy to learn how to use and it helps solidify concepts well.

Easy to use. Descriptive and relevant to material.

Understanding how experiments are done to collect the necessary data. Working with money instead of points, because it's fun to see how much you made.

It helps me learn the different types of reactors. It helps me understand what goes on in the reactor.

It tests your knowledge and applies it to "real" life problems. It is very self explanatory.

It teaches how to solve problems related to the course and you can go back and finish a quiz if you had left it.

I like the pictures of the reactors and that you can vary many parameters easily to see its effect on reactions and then graph different things very easily.

Develops a good understanding on material. Quizzes allow you to check your work.

Fun. Made homework more interesting.

Realistic examles of useful reactors. Utilizes computer for painstaking number crunching.

Really easy to understand, user friendly.

Like mentioned above, it gives greater understanding of Fogler's concepts. I also like the labs (SO_2 oxidation, D1L1, D2L2, D3L3).

Fast. Gives a lot of useful data.

The actuality of doing the labs is very beneficial.

I get a visual feel for what's going on. A nice break from the book.

It provides a visual means to learn the information which makes the learned theory easier to comprehend. It also serves as a great way to double check hand calculations as you can manipulate design variables very easily.

Works well for taking derivatives and integrals to solve quizzes.

It automatically tells you if the data is incompatible, i.e., in D2L2 PFR it tells you if the reactor needs to be bigger or smaller based on the outlet pressure. That you can leave a quiz and return to it at a later date.

It helps with the problems on the exam that deal with sets of data.

Info sections are great - gives important tips in understanding the reactions. The 3D effects of the reactor in action.

It is very helpful in bridging the gap between experimental results and using learned equations. It is easy to save and plot data.

Helps give great examples to learn the material. A great visual tool for learning about reactors.

It helped me gauge my understanding.

Nice visualization. Gives data points so you can plot and analyze your answer.

QUESTION 4:

What changes to existing labs or functions do you suggest?

QUESTION 4 RESPONSES:

Maybe have a function that can plot an entire reaction profile for a CSTR or PFR for the particle diameter vs. conversion graph.

Bring in a laptop to class to show what we need to do.

On one of the last quizzes we did for homework, I had some trouble getting anything to happen, and ended up resetting the quiz a bunch of times before it would work.

A save plot function. Bigger error margins for finding activation energies.

Maybe some additional info in the info tab to make it easier to solve the complex problems.

Try to make sure that with one strategy it will work or more than one solution is possible for different strategies.

More explanation of processes. Add a bigger variety of quiz types instead of solving for the same parameters.

Reset should let the problem to go back to original data instead of the current one.

When I enter the same data, I would like to see the same results.

Maybe a list of useful equations.

More sequence or series of reactors.

To D2L2 CSTR maybe in the quiz the values of eta, phi, and omega could be shown.

Change something about the scattering.

Saving files in Excel format. More data to exclude data irregularity.

It would be nice to have buttons which could increment values instead of having to always type them in.

Some quizzes need the plus/minus range increased because of the data. I believe it is one of the early quizzes with a PFR.

None.

Nothing really.

QUESTION 5:

What are the first two new labs or functions that should be added to the Lab?

QUESTION 5 RESPONSES:

Stuff we didn't cover.

More different types of reactors.

Not sure, seems that it covers most of the text.

More plotting options, e.g., log scales.

Ability to create own reactor. Add more regarding catalyst pellets.

Add slab catalyst pellets to D2L2. Allow for integration of design equations.

A lab to find ΔH due to variations of conversion and T with respect to z.

Actual systems instead of just reactors.

Hints. Detailed steps to follow for examples.

Excel format tables. PolyMath.

Multi-stage reactors. Possibly a Save function to save your spot in Reactor Lab easier.

It pretty much covered everything we went over in class.

QUESTION 6:

Would display of the Lab during <u>lecture</u> be helpful?

QUESTION 6 RESPONSES:

Yes. [total of 5 plain "Yes"]

No. [total of 2 plain "No"]

Very much so.

Somewhat, or maybe just a few steps given to help solve the quizzes.

Not really, it's self explanatory.

Yes, very!

No, I don't think so.

Yes, very helpful.

Yes. Should explain how to use the program thoroughly.

Yes. At first I was confused as to what I was supposed to do.

What you are doing now is adequate.

Yes. Initially it was hard to locate stored data that was necessary for plots. A brief demonstration would be helpful, but it is otherwise straight forward and serves as a great supplement to lecture and to homework assignments.

No, or maybe.

Yes. It took me a little while to grasp moving around the Lab. It always helps to have a visual.

Maybe during the 1st week. Other than that, not really.

Yes definitely.

Maybe in the problem sessions for an easier time with homework but not in lecture.

No because struggling with it helps you learn.

QUESTION 7:

What did you find on the <u>Web</u> that was helpful in this course?

QUESTION 7 RESPONSES:

The class links to integral tables was useful.

NIST. And course notes.

Course notes.

Course notes and when the homework was due.

Course notes. Links to other sites.

Nothing other than the class website.

Notes and help section.

Your course notes were great.

Notes from CENG 113 website.

The CD in Fogler text that sort of connected with the web was quite helpful.

The course website.

The web page, class notes.

Course notes.

The rate Arrhenius equation. And the use of all types of rate equations for all reactors.

Nothing.

Notes for thermal effects.

QUESTION 8:

Did you look at the lab module that showed reactant concentration profile in a catalyst pellet and did you change inputs like pellet diameter and rate constant?

QUESTION 8 RESPONSES:

I looked at it and it was useful because I could interactively supplement my previous knowledge.

Yes, a little. Would have been an excellent demo for class, though.

No.

Yes. [total of 5 plain "Yes"]

Yes. I had to for homework. It was good.

I don't think I did.

Yes but I barely changed the pellet diameter. I mainly played with the rate constant.