AC 2012-4691: THE IMPACT OF STUDIO-BASED LEARNING ON THE DELIVERY OF COURSE INFORMATION

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The Impact of Studio-based Learning on the Delivery of Course Information

Studio-based learning techniques have been used in variety of disciplines, most often in architecture and fine arts. In a studio-based learning experience, students learn not just by doing but also by receiving critiques on their work from other students as well as providing critiques themselves to other students. Engineering students often do this in informal settings (e.g., study groups) but rarely do so in a formal classroom setting. The critiquing activity is the strength of the learning activities in studio-based learning as it requires students to be active as well as encouraging students to evaluate and explain (teach) the material to others, thus strengthening their understanding of the concepts.

Over the past few years a team from the chemical engineering program and the computer science program have been working on developing a software package to aid students in developing their skills in the material and energy balance course in the chemical engineering curriculum. This software package was developed to assist students in converting written descriptions into a graphical format and then into a mathematical representation. The software includes a number of messages designed to help the students overcome typical errors when trying to formulate problem solutions to typical material and energy balance problems. This messaging activity in the software was designed to play the role of an expert in the field who would not tell the students the answer but would prompt them to examine what they had done that did not seem proper.

The messaging component of the software has proven to increase student accuracy in solving material/energy balance problems while also increasing the carry-over of these skills to solving problems when the messaging was not provided. We have also used the software in a studio-based approach style since the software provides a common platform for the students to use in providing/receiving critiques. Preliminary data suggests that the use of the software, in its current form, is not optimal for use in a studio-based approach. In particular, the current messaging system provides enough guidance that the resulting critiques lack substance since most of the questions/difficulties have already been addressed. As a result the critiquing activity in the studio-based approach adds little to the student's understanding. It appears that the software but without the error messaging system activated may provide a better means for promoting discussion during critiquing periods in a studio-based teaching approach. We are currently in the process of testing whether student skills are increased more by using the software with the messaging turned on in a traditional teaching approach or by using the software with the messaging turned off but in a studio-based teaching approach.

Studio-Based Learning

Studio-based learning (SBL) techniques have been used in a variety of disciplines, most notably in architectural education.[1] The technique is rooted in a type of constructivist learning theory called sociocultural constructivism.[2] The studio-based approach typically encompasses four key steps (see Figure 1).[3] First, students are given complex and meaningful problems for which they have to *construct* solutions. Second, students *present* their solutions and justifications to the entire class for discussion and feedback. Third, students' peers *critique* their solutions and provide comments. Finally, students are given the opportunity to *respond* to comments and criticisms, and to modify their solutions appropriately.

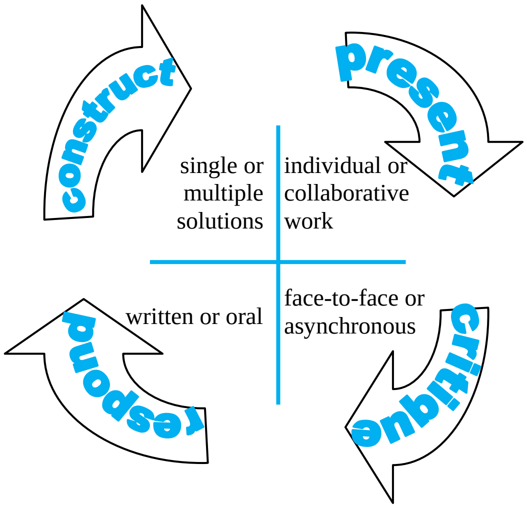


Figure 1. Schematic of SBL Model

Note that SBL, as defined above, differs from a variety of other instructional techniques that also use the terminology "studio". Among the more notable is the Scale-Up[4] program introduced at North Carolina State University. In Scale-Up programs students experience a mixture of presentations, desktop experiments, web-based assignments and collaborative exercises while working in small groups using networked laptops (studio labs). This approach requires active participation by the student as well as providing an open-ended problem-solving environment. While the critiquing and response aspect of SBL may take place during this approach it is not a required part of the course.

SBL, like Scale-Up, is clearly an "active" learning technique requiring much more from the learner than a typical lecture formatted class. As has been cited by many authors, and summarized by Prince,[5] active learning provides a much fuller educational experience. In addition to the several advantages of being an active learning technique, SBL also addresses all six cognitive levels of Bloom's taxonomy.[6] Of particular importance is the critique phase of SBL wherein the *Evaluation* level of the taxonomy is clearly invoked. This aspect of learning is not incorporated in many active learning procedures but clearly is an essential part of SBL.

A drawback to the implementation of SBL in a traditional class is the time constraint. As the title suggests, this technique has most frequently been used in studio-based classes. Thus the class time allotted for the class is more typical of that for a laboratory class in engineering, two to three hours. So while the SBL approach might work in a class for which an extended recitation section is part of the class, the time constraints inherent in a typical one-hour class would seem to be a large impediment for using SBL. With the advent of the numerous, asynchronous communication media now available this no longer need be a barrier.

Prior Work

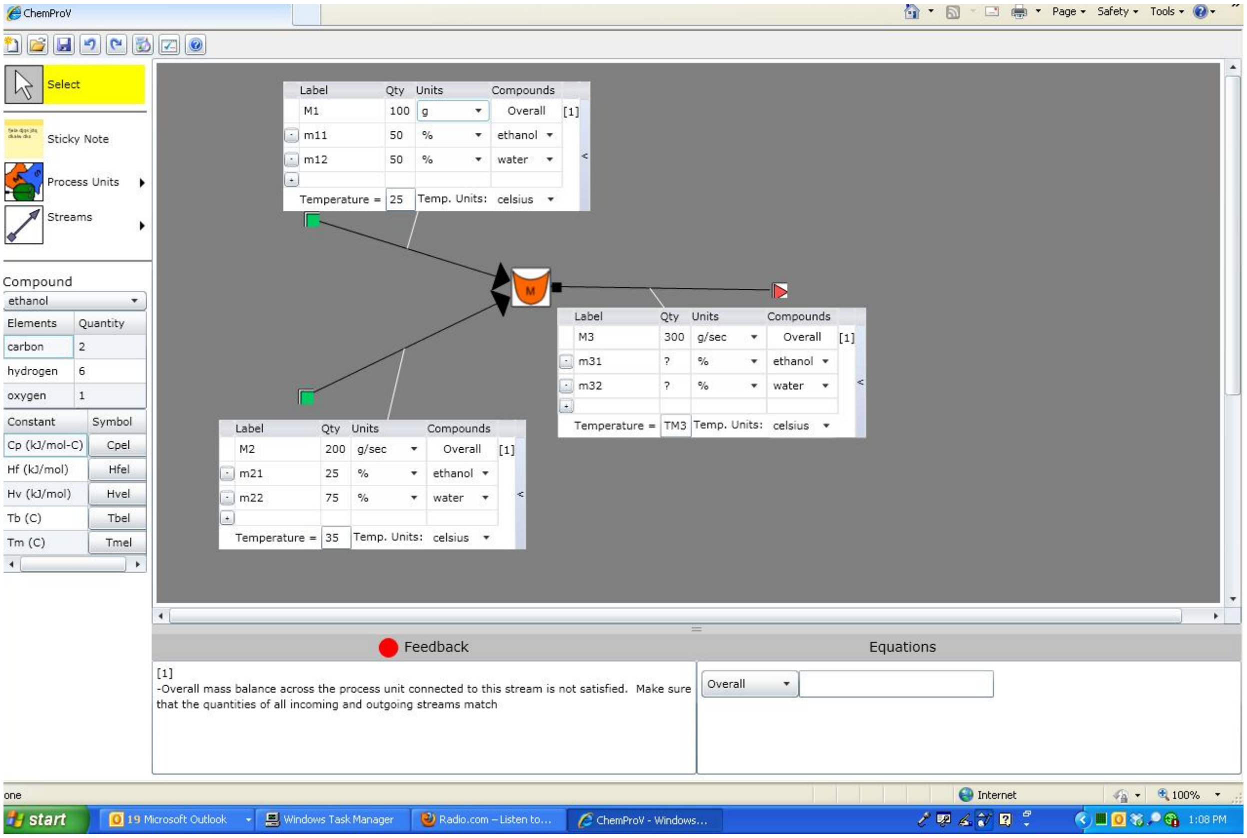
The desire to seek improvements in teaching strategies in material/energy balance classes started with the observation that approximately 35% of the students enrolling in such classes either dropped out of the class, failed the class or received a grade lower than a "C". This statistic seemed to be constant no matter who taught the course and also appeared to be the situation at other universities. In 2006 pairs of students from the material/energy balance course were asked to participate in a laboratory study in which they were observed solving problems typical of the class. During these observations it was noted that students struggled with two major problems – translating the written problem descriptions into an appropriate graphical representation (process flow diagram) then translating the information from the diagram into mathematical expressions.[7]

As Felder and Silverman[8] have found, the majority of engineering students at the college level are visual learners. Thus, providing a visual environment for solving material/energy balance problems should help the students gain the skills needed to solve these problems.

In response to these observations we began the development of a software tool designed to provide a scaffolded environment to help the students through these two translations. In creating ChemProV (Chemical Process Visualizer), we wanted to aid the students in building their own skills in transforming written information into visual form, without giving them so much aid that the software becomes a crutch. Grounded in the learning theory of Vtogsky,[9] this approach is in line with a rich legacy of software scaffolding approaches[10,11] in which learners are initially aided by modifications to problems that make them initially more doable; the modifications are then gradually removed as learners gain more skills. The tool would, in addition, give students an opportunity for early success in the material/energy balance class, leading to enhanced learning according to self-efficacy theory.[12]

Unlike typical process simulation packages (HYSYS, ASPEN, PRO/II), in ChemProV the development of the process flow diagram and the needed balance equations were left entirely to the students and no numerical solution programming was provided. A number of other educational software programs for material/energy balance classes have recently appeared, for example the offerings of Sapling Learning. These tend to be overly prescriptive in the problem solving procedure employed thus reducing the educational experience for the student. The goal of ChemProV was to provide a scaffold for learning but leave the problem solving strategy flexible enough to accommodate multiple learning styles and approaches. The intent was that by the end of a typical material/energy balance class the students would have developed their skills to the point where the use of ChemProV was no longer necessary.

An example of a ChemProV screen is shown below. This is the process flow diagram (PFD) for a simple mixing operation where two streams containing ethanol and water are mixed. Note that the overall specification for each of the streams has been highlighted with a [1]. In the "Feedback" section at the bottom is a message to the user that the overall mass balance has not been satisfied, in this case because of the mismatch in the units between stream 1 and streams 2 and 3. This feedback mechanism is used to help the user assemble a proper PFD insuring that all components that enter the system also leave and that there is a consistency of units. The user then can use the various labels from each stream to construct balance equations in the "Equations" section at the bottom right. ChemProV also checks these equations to insure their correctness and independence. When the proper balances have been constructed the red dot in the "Feedback" section turns green and all feedback messages will disappear. At this point the student may complete the numerical calculations using any tool they desire (calculator, Excel, Matlab, etc.). The goal of using ChemProV is not to solve material and energy balances, as HYSYS, ASPEN and other process simulators do. The goal of ChemProV is to develop the problem-solving skills that students will need to be successful as chemical engineers.



Compound: ethanol

Elements	Quantity
carbon	2
hydrogen	6
oxygen	1

Constant	Symbol
Cp (kJ/mol-C)	Cpel
Hf (kJ/mol)	Hfel
Hv (kJ/mol)	Hvel
Tb (C)	Tbel
Tm (C)	Tmel

Label	Qty	Units	Compounds	
M1	100	g	Overall	[1]
m11	50	%	ethanol	
m12	50	%	water	

Temperature = 25 Temp. Units: celsius

Label	Qty	Units	Compounds	
M3	300	g/sec	Overall	[1]
m31	?	%	ethanol	
m32	?	%	water	

Temperature = TM3 Temp. Units: celsius

Label	Qty	Units	Compounds	
M2	200	g/sec	Overall	[1]
m21	25	%	ethanol	
m22	75	%	water	

Temperature = 35 Temp. Units: celsius

[1]
-Overall mass balance across the process unit connected to this stream is not satisfied. Make sure that the quantities of all incoming and outgoing streams match

Equations: Overall

Figure 2: Screen shot of a ChemProV session

In 2008 and 2009 laboratory sessions were conducted to assess the effectiveness of ChemProV. In conducting these experiments the material/energy balance class was divided into four groups. Two different material balance problems, of equal difficulty, were developed. Each group was asked to solve two problems; one problem to be solved using a full version of ChemProV and the other problem using a version of ChemProV with the feedback messaging system turned off. It is through the feedback messaging system that the scaffold is provided for the students. The version of ChemProV used and the order of the problems solved were fully mixed.

As hoped the results showed that the two problems were statistically identical in terms of difficulty. Thus we could focus on the effect of the scaffolding supplied by ChemProV on the development of student skills. The results of this analysis are shown below.[13] As shown in this figure the group that solved their first problem using the full version of ChemProV had a statistically significant improvement in solution accuracy when compared with the group using ChemProV without the feedback messages. When the group that did not have the full version of ChemProV now solved the second problem, using the full version of ChemProV, the accuracy of their solutions also showed a statistically significant improvement in accuracy (the No Feedback First results shown for Task 2 in the figure). Most importantly, the group that used the full version of ChemProV first then used the version of ChemProV without the feedback messages for their second problem (the Feedback First results shown for Task 2) showed improved accuracy when solving the second problem (without the feedback messages) but, more

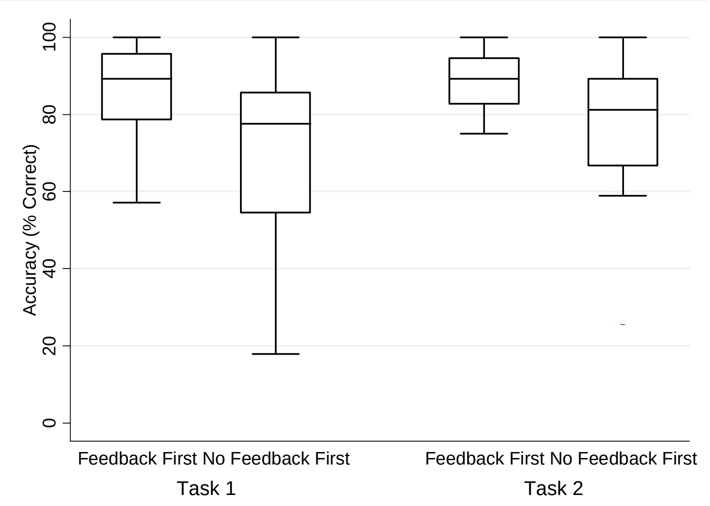


Figure 3: Box plot of solution accuracy by condition and task

importantly, continued to outperform the other group of students at a statistically significant level. These results demonstrated that ChemProV was satisfying its desired goals. It provided a learning environment in which students could learn the skills needed to successfully solve material/energy balance problems. In addition, these skills remained with the students into situations where no feedback was being provided. Although not shown above a second observation was that using the full version of ChemProV resulted in significantly more time on task when compared with time on task for the no feedback version of ChemProV.

Incorporating SBL into Material/Energy Balance Classes

While the results described above were encouraging the development of ChemProV also opened the opportunity for overcoming the difficulties in using SBL in a material/energy balance class. In 2011 a group of students from an introductory chemical engineering class were recruited to solve a typical material balance problem using ChemProV in an SBL environment. Twelve pairs of students (6 pairs each on two separate nights) worked on different problems using ChemProV. While the students had received some instruction on solving material balance problems none had taken the material/energy balance class. After allowing some time for each group to solve their problem copies of all problem statements were given to every group and each group was invited to present their solution to the remaining groups. ChemProV plays an important role in implementing the SBL approach by providing a common tool and format for each group's presentation. This made it easier for the groups to understand what the presenting group was trying to accomplish and thus easier to offer suggestions about how to solve the problem (if the presenting group was stuck), correct any errors that might be present in the solution that was presented, or on alternatives to the solution offered. No attempt was made to assess the effectiveness of the SBL approach during this trial but attitudinal surveys indicated that the students liked the format and felt they had learned from the experience.

An interesting observation arose when comparing the results between the two evenings. On the first evening the groups used a full version of ChemProV when solving their problems. On the second evening the groups used the version of ChemProV without the feedback messaging. During the critiquing portion of the evening, when the full version of ChemProV had been used, the discussions among the groups were rather limited. Often this resulted from the fact that ChemProV had provided enough guidance that the solutions presented were full and correct. The solutions presented during the second evening were not as complete and contained more areas where either the groups could not find a solution or had an error in their solution. The resulting discussions were much fuller and involved many more of the students.

The sessions described above took place during a 2 – 3 hour time block in the evening. As noted above, SBL has been used for these extended class periods before. The difficulty in implementing SBL is that the technique does not fit well with a typical one-hour per session class structure. This limitation can be overcome by using on-line asynchronous communications software, thus allowing students to move through the SBL cycle on their own schedule.

One of the authors has developed an asynchronous software program for use in computer science courses. This software, OSBLE (Online Studio-Based Learning Environment), provides an online environment designed to facilitate peer review of students' code solutions.[14] OSBLE supports three user interfaces: (a) student; (b) instructor; and (c) code moderator. Students submit code solutions to be reviewed through the system. Once they have done so, their solutions become "locked": they may no longer modify them, but they now have access to the code solutions of their peers. Thus, a period of on-line code review can begin. Students are encouraged to view the solutions of the members of their review team, to identify issues with those solutions, and to log those issues in the system. In an empirical evaluation of OSBLE, we found that it not only eased the logistics of implementing code reviews, but also improved the organization and efficiency of the review process.

Current Status

While OSBLE was intended for use as a SBL tool for code review it can be integrated with ChemProV to now provide an SBL tool for use in material/energy balance classes. Doing so would provide not only the scaffolded learning tool provided by ChemProV but also the advantages of active learning and evaluation provided by the SBL approach. To this end we have initiated a study in which a SBL approach, incorporating ChemProV, will be implemented in material/energy balance classes. The effectiveness of this approach will be compared with current teaching approaches in these classes, none of which use SBL or ChemProV.

The plan for the assessment of the OBSLE/ChemProV combination involved recruiting seven other universities to participate in the study. At each of the schools the participating faculty agreed to teach their material/energy balance class in their normal fashion during the 2011-2012 academic year. Also during this time ChemProV was being upgraded to include the capability of accommodating both material balances and energy balances. In addition, ChemProV is being integrated into the OSBLE structure to allow for an asynchronous SBL implementation. In the 2012-2013 academic year each of the participating universities then will teach the material/energy balance class but now using the OSBLE/ChemProV combination.

To determine the impact that the use of OSBLE/ChemProV might have on student learning the following assessment scheme is planned. Some of the participating schools teach a combined material/energy balance class; others separate the two into a material balance class and an energy balance class while still others teach on other schedules. In some of the schools recitation/problem-solving sessions are provided in addition to the normal classroom hours, in others they are not. Thus three different levels of problems were developed; one involving only material balances on a non-reacting system, one involving only material balances but now on a reacting system, and one involving material and energy balances on reacting systems with recycle. At each level there are two problems. The first is a typical problem where students are given a description of a process then asked to develop the process flow diagram and the equations needed to perform the material (and energy if necessary) balances. The second problem (a critiquing problem) consists of a problem statement, a process flow diagram, and a set of balance equations. The process flow diagram and the equations contain errors. The students are asked to find the errors, explain why they are erroneous, and suggest a way to fix the error.

In order to build a community among the faculty commited to this project we conducted a two-day workshop prior to the 2011ASEE Annual Conference on June 25 – 26, 2011. During this workshop the participating faculty worked in pairs, using ChemProV, on problems similar to those which the students will be asked to solve. This was followed by a discussion period, similar to a studio-based environment, where each pair described their problem, its solution, and any limitations they found in using ChemProV. The group then was shown video clips from the SBL implementation study from 2011 and a presentation on OSBLE. Based on exit survey responses, the workshop succeeded in motivating participants to try SBL approaches in their own courses, and provided them with a high level of preparation for doing so. Moreover, attendees were highly satisfied with the workshop. On a scale of 1 to 10, participants rated their overall satisfaction with the workshop as a 9.

Assessment

Evaluation of this approach to instruction in the material/energy balance class is proceeding as follows. At the start of the semester, in the appropriate class, the participating faculty will give both the standard format problem and the critiquing problem to the students in the class. The level of the problems will be selected from among the three levels to be commensurate with the expectations of what the students should know by the end of that class (e.g., material balances only or material and energy balances). At the end of the semester the students are given the same two problems again. Scoring rubrics have been developed for both problems so that the pre- and post-class problem results can be compared to determine how much the students have learned. The amount of change from the 2011-2012 academic year (normal teaching strategy) can then be compared with the change from the 2012-2013 academic year (OSBLE/ChemProV).

In addition to these results students are also asked to complete attitudinal surveys at both the start and the end of the class. To measure attitudinal changes, we used modified forms of the Motivated Strategies for Learning Questionnaire (MSLQ)[15] coupled with the Classroom Community Scale (CCS)[16]. The results of these surveys have now been collected from the schools that taught the appropriate classes during the fall semester (quarter). The other participating universities will be completing the surveys in the spring. The results from this baseline year will be reported in June.

Conclusion

Studio Based Learning (SBL) offers many advantages for student instruction. In addition to being an active learning technique the construct-present-critique-respond cycle within SBL address all six cognitive levels of Bloom's taxonomy. An impediment to the incorporation of SBL in a typical class is the time constraint imposed by the usual one-hour long time block for most classes. We have combined two software programs to overcome this difficulty. ChemProV is a scaffolded learning tool that has demonstrated effectiveness in assisting student learning in material and energy balance classes. OSBLE is an on-line asynchronous studio-based communications software that allows the implementation of SBL outside of the classroom. When combined OSBLE provides the potential for SBL outside the usual one-hour class time constraint while ChemProV provides a structured environment that makes communication of material/energy balance problems easier. Testing is currently underway to determine baseline data from traditional teaching approaches in material/energy balance classes. In the 2012-2013 academic year data from seven universities will be collected allowing an assessment of the effectiveness of the OSBLE/ ChemProV approach against this baseline data.

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