The Enhancement of Students' Learning in Both Lower-Division and Upper-Division Classes by A QUIZ-BASED APPROACH

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Increasing students' learning and success is very important in any engineering school. The ABET accreditation program values the students' learning and success in chemical engineering (ChE) programs nationwide. The Department of Chemical Engineering at California State University at Long Beach (CSULB) has established program objectives that include developing pedagogical techniques to enhance the students' ability to learn and solve complex problems.

Material and Energy Balance (ChE 200), which is the first core course in ChE curriculum at California State University, is a very important and challenging class with a historically high failure rate. Usually, students take this course in their third semester (sophomore year). The required textbook for this class is the last edition of the *Elementary Principles of Chemical Processes*.[1] According to the literature, the solution manual for this textbook is easily obtainable from the Internet for most students.[2] Many of the students often complain that the course is very hard and demanding for them. In other universities, modifications have been made to this course to make it easier to understand for undergraduate students.[2-7] For example, it has been shown previously that using personalized online homework assignments can improve student achievement.[2] Using such technologies in a classroom, however, depends on the availability of resources. At CSULB, a simple and cheap quiz-based method was applied to modify the Material and Energy Balance course (ChE 200).

Homework assignments are invaluable educational tools used to help students to acquire critical-thinking and problem-solving skills.[2] If students possess weak math skills or do not know how to properly set up and solve the problems, the instructor can have them practice more by giving them more homework assignments. Traditionally, an important component of the ChE 200 course was the individual homework assignments, which were worth about 15% of the total grade. Most of the homework (HW) problems were taken from the textbook.[1] Since most students wish to get this 15% to boost their final grade, many used the easily available solution manual or copied each other's work without understanding the concept.[8] To overcome the problem of cheating, the use of personalized online homework assignments has been previously tried in other schools.[2] At the CSULB Chemical Engineering Department, a different approach was recently adopted to overcome this problem and ultimately enhance the students' learning. In ChE 200 course, the traditional homework assignments were completely replaced with weekly paper quizzes that were worth 15% of the total grade. In order to ensure the effectiveness of this approach, the author applied the same approach to an upper-division course (Chemical Reactor Kinetics, ChE 430). The results of this change were compared with those for the lower-division class (ChE 200). It should be mentioned that both classes were curved.

The goal of this paper is to examine the effectiveness of the quizzes on students' learning in teaching upper-division and lower-division courses in chemical engineering. Specific emphasis has been placed on the study of replacing traditional homework assignments with weekly quizzes in Material and Energy Balance (ChE 200) and Chemical Reactor Kinetics (ChE 430) classes.

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IMPLEMENTATION

The author taught both the lower-division (ChE 200) and the upper-division (ChE 430) courses in this study with similar class sizes (between 32 and 42 students in each class). The HW-based approach was used in the Fall 2010 semester and the quiz-based approach was introduced and tried in the Fall 2011 semester. Three exams were given throughout these semesters in each class. The lecture notes were identical before the change and after for both cases. The exams given to the quiz-based class were similar (with similar difficulties) to the HW-based class and the exam problems were not drawn from the HW solutions. A teaching assistant helped with grading both HW-based and quiz-based classes. The instructor and the TA were the same before and after the change. The only difference between the Fall 2010 class and that of Fall 2011 was the homework assignments.

In both studies, a set of the textbook problems was posted to the course website (Blackboard) each week. There were a total of nine different sets of HW in a semester. In the HW-based approach, students were assigned to solve the weekly problems and submit their handwritten solutions individually. The homework assignments were graded for credit (15% of the total grade) and returned to students. In the quiz-based approach, after posting the weekly HW, the students were highly encouraged to work in groups to solve the homework problems. The students were not, however, required to submit their HW assignments. Subsequently, a 15-minute paper quiz was scheduled five days after posting the HW problems. One of the problems from the HW was chosen randomly and given to students as a quiz. The weekly quiz was closed-book and closed-notes and was given to students in the beginning of the class. It should be noted that the solutions to the homework problems were posted to the course website one day ahead of the scheduled weekly quiz so that students had enough time to go through the solutions. The weekly HW consisted of six to 10 problems and some of these HW problems had long solutions. The students did not know which problem would be on the weekly quiz and they had to learn the solution methods to all problems to get full quiz credit. Thus, the students were less likely to memorize the solutions and still be able to do well on the closed-book/closed-notes quizzes. Also, the students were not allowed to bring anything to the quiz session except pencils and simple calculators. Laptops and cell phones were not allowed during the quiz. Since there was no requirement to submit the HW to the instructor, students had no incentive to cheat. The students did not use the solution manual or did not copy each other's work because no HW submission was required. After the solutions were posted and in order to help students understand the solutions better, the instructor was available during office hours in the day before the quiz. Similarly, the weekly quizzes were graded for credit (15% of the total grade) and were returned to students so they could see their mistakes. To support weaker students in the class, the lowest score of their HWs and quizzes was eliminated in 2010 and 2011 respectively.

RESULTS AND COURSE ASSESSMENT

To assess the learning outcomes, the quantitative data from students' work in both ChE 200 and ChE 430 courses were collected and analyzed. After implementation of the quiz-based learning idea, the students' performance in the two midterms and final exams was studied and analyzed using statistical tools and compared with the old procedure. The results are shown in Table 1.

According to Table 1, a comparison between the HW-based approach and the quiz-based approach indicates an improvement in the students' performance in both lower-division and upper-division courses. In both courses, students earned higher exam grades when traditional HWs were completely replaced with weekly quizzes. The class GPA was also higher; as an example, the class GPA in ChE 200 increased from 2.2 to 2.95. Based on the study, more students earned

TABLE 1
Exam Results in Lower-Division and Upper-Division Courses

Course	Average midterm exam #1 (Max: 100)		Average midterm exam #2 (Max: 100)		Average final exam (Max:100)	
	Before (HW-based)	After (Quiz-based)	Before (HW-based)	After (Quiz-based)	Before (HW-based)	After (Quiz-based)
ChE 200: Material and Energy Balance	63.93 (Class size: 32) (Standard deviation: 28.75)	80.53 (Class size: 34) (Standard deviation: 15.88)	50.05 (Class size: 32) (Standard deviation: 30.47)	64.35 (Class size: 34) (Standard deviation: 21.76)	60.44 (Class size: 32) (Standard deviation: 23.64)	64.34 (Class size: 34) (Standard deviation: 19.32)
ChE 430: Chemical Reactor Kinetics	67.50 (Class size: 42) (Standard deviation: 24.45)	73.90 (Class size: 32) (Standard deviation: 18.70)	60.46 (Class size: 42) (Standard deviation: 22.56)	66.39 (Class size: 32) (Standard deviation: 20.06)	68.89 (Class size: 42) (Standard deviation: 25.08)	71.23 (Class size: 32) (Standard deviation: 18.30)

A's and B's in the newer approach. In the lower-division class, the percentage of students who received A and B after the change was respectively 10.5% and 11% higher than before the change. The standard deviations were smaller for the results of exams in the new approach. To compare the exam averages, t test was performed. The t test showed that in the lower-division class (ChE 200) the results were more statistically significant than those in the upper-division class (ChE 430). Most of students at the senior level are more mature and they usually can find their own ways to study and learn. For this reason, the quiz-based approach shows more impact on students at the sophomore level (*i.e.*, lower-division class). It is worth noting that the instructor effectiveness was also rated higher after this change in the two courses.

According to Table 1 for the lower-division class, there is a 26 and 28 percent rise in midterm scores after replacing HWs with quizzes, but only a 6.5 percent increase in the final exam. This is because final exams are longer, cumulative, and usually more stressful for students compared to midterms. The grade improvement for the upper-division class during the exams (9.5 and 9.8 percent increase for midterms and 3.4 percent increase for the final) is less than that for the lower-division class. As discussed before, this could be due to the maturity of students in upper-division classes.

In addition to collecting and analyzing the students' scores on the exams throughout the semester, another course assessment was conducted at the end of semester. A course assessment survey consisting of four questions was given to students at the last class meeting day. The survey form is shown in Table 2. The students were requested to answer the questions in the survey anonymously. By completing the survey, the students provided their feedback on how the course's expected outcomes were achieved. There were five scales in the survey form, with 5 being strongly agree and 1 being strongly disagree.

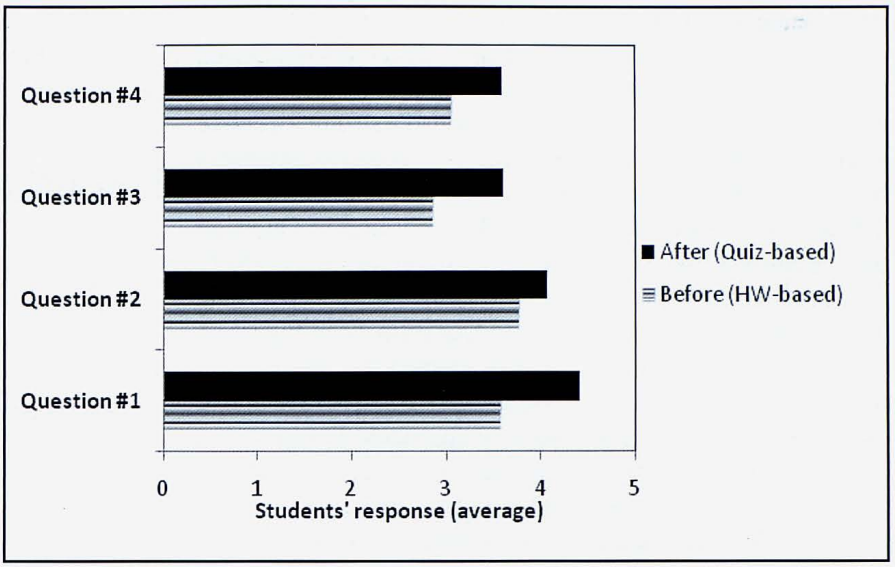

Figure 1. *Course survey results for the Material and Energy Balance class (ChE 200). For listing of items surveyed, see Table 2.*

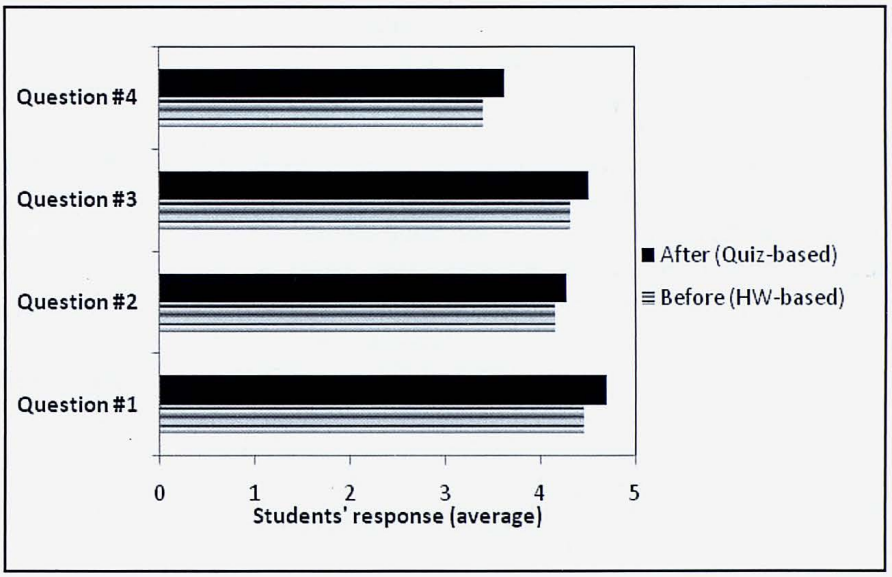

Figure 2. *Course survey results for the Reactor Kinetics class (ChE 430). For listing of items surveyed, see Table 2.*

The students' responses to the survey are shown in Figures 1 and 2. As seen in the figures, after implementing the new strategy, the students' problem-solving skills were improved (23.5% improvement for ChE 200 and 6%

TABLE 2
Course Assessment Survey for ChE 200[1]

	Question	Scale
1	This course developed my ability to solve problems.	Strongly agree 5 4 3 2 1 Strongly disagree
2	I learned to write mass balance equations for simple and complicated systems.	Strongly agree 5 4 3 2 1 Strongly disagree
3	This course developed my ability to work with others.	Strongly agree 5 4 3 2 1Strongly disagree
4	About how many hours per week did you spend studying for this course?	Five hours or more 5 4 3 2 1 One hour or less

Note 1: For ChE 430, a similar survey form was used. The only difference was question #2. For ChE 430, question #2 was changed to : I am able to design a simple reactor using hand calculations.

improvement for ChE 430 according to Question #1). Before using this approach, a large group of students was struggling to grasp the key concepts and constantly finding themselves in danger of failing. For this reason, they had a strong incentive to cheat. Replacing HWs with quizzes led to more studying hours for each student in the class (17.8% increase for ChE 200 and 6.5% increase for ChE 430 according to Question #4 in Figures 1 and 2). More time spent on the course materials resulted in improved learning and better performance. The results of students' answers to Question #2 in Figures 1 and 2 clearly showed that students learned the concept and that students' learning increased by 8.25% and 3.13% in two classes after implementing the new approach. Furthermore, according to Question #3 in Figures 1 and 2, the students' teamwork skills improved (for example, 26% improvement for ChE-200 class) because most of them worked with their classmates to get prepared for the quizzes.

In the author's opinion, the new approach has some benefits compared to the old approach. Based on the author's observations, the quiz-based method appeared to be more interactive when compared to the old approach. The author observed more student engagement in the new approach. The class attendance increased and more questions were asked by students during the lecture. Also, more students showed up in the weekly office hours. Moreover, the quizzes were easier and took much less time to grade, allowing the instructor to focus more on lecture notes and other class materials. This is because quizzes are usually shorter in length than HWs (each HW has at least six problems, while each quiz contains only one problem). Most importantly, in the new approach, students had to study every week to pass the weekly quizzes. This gradual studying over the semester not only helped them retain knowledge, it helped them to get prepared for the exams and prevented them from cramming at the last minute before the tests. In summary, the list of benefits of the quiz-based approach is given below:

- *Improves problem-solving skills and enhances students' learning.*
- *Limits cheating (limits using the solution manual or copying other students' work).*
- *Increases class attendance.*
- *Motivates students to study.*
- *Encourages students to show up in office hours.*
- *Encourages students to study in groups.*
- *Easy to grade.*

Maybe the only noticeable disadvantage of this approach will be that quizzes will take 15 minutes of the class time each week. By condensing the time spent on less-important class materials, however, the instructor prevented this lost time from adversely affecting the class coverage.

CONCLUSIONS

Some modifications were made to lower-division (Material and Energy Balance) and upper-division (Chemical Reactor Kinetics) classes to improve the students' study habits and enhance students' performance and learning. The results indicated that students performed better and were more successful when grading for weekly homework assignments was completely replaced with grading for weekly quizzes. According to the comparison between the lower-division and upper-division classes, the author believes that the modification made in lower-division class (Material and Energy Balance) has more impact on students compared to the upper-division class. The new approach motivated students and created a driving force for them to work harder and study more, and was more effective to prevent them from cheating. Overall, the quiz-based approach was found to be effective to enhance students' learning and problem-solving skills.

ACKNOWLEDGMENTS

The author thanks the Chemical Engineering Department at CSULB for supporting this study. The author would also like to express thanks to Hamidreza Farrokhpayam, who helped with manuscript preparation.

REFERENCES

1. Felder, R.M., and R.W. Rousseau "Elementary Principles of Chemical Processes," New York, John Wiley & Sons (2005)
2. Liberatore, M.W., "Improved Student Achievement Using Personalized Online Homework for a Course in Material and Energy Balances," *Chem. Eng. Ed.*, **45**(3), 184 (2011)
3. Miller, D.C., M.H. Hariri, M. Misovich, M. Anklam, and R. Artigue, "A Modified Approach to Material and Energy Balances," Proceedings of the ASEE Annual Conference (2002)
4. Bullard, L.G., and R.M. Felder, "A Student-Centered Approach to Teaching Material and Energy Balances 1. Course Design," *Chem. Eng. Ed.*, **41**(2), 93, (2007)
5. Bullard, L.G., and R.M. Felder, "A Student-Centered Approach to Teaching Material and Energy Balances 2. Course Delivery and Assessment," *Chem. Eng. Ed.*, **41**(3), 167, (2007)
6. Scranton, A.B., R.M. Russell, N. Basker, and L.C. Scranton, "Teaching Material and Energy Balances on the Internet," Proceedings of the ASEE Annual Conference (1999)
7. Rossiter, D., R. Petrulis, and C.A. Biggs, "A Blended Approach to Problem-Based Learning in the Freshman Year," *Chem. Eng. Ed.*, **44**(7), 23, (2010)
8. Felder, R.M., "How to Stop Cheating (or at Least Slow it Down)," *Chem. Eng. Ed.*, **45**(1), 37, (2011) ❐