KNOWLEDGE DECAY AND CONTENT RETENTION OF STUDENTS IN FIRST-SEMETESTER GENERAL CHEMISTRY

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Abstract Topics typical of general chemistry I content that need to be mastered have not changed in over 15 years, but the tools available to assist students in learning general chemistry have. Striving to enhance motivation and give students the practice needed for learning first-semester general chemistry were the reasons behind this case study on the advantages and drawbacks to using electronic homework (e-homework). The effectiveness of online homework is important and needs to be evaluated. The questions that therefore arise are: Are commercially available Information and Communication Technology (ICT) tools going to motivate and encourage students to complete the assignments required, and if so, will their use improve the students' success rate in general chemistry? This case study (n = 1,947) covered a 14-semester span and the use of seven different commercial systems. Of the 1,090 students who voted, 70.7% felt as though the e-homework had been valuable enough to them that it should be continued. Contributions from this study highlight how well do students perform in the class and how well they perform when they advanced to the next general chemistry class. The impacts of e-homework on prevention of knowledge decay and content retention are provided. One of the advantages to using e-homework is that students who master their e-assignments (≥ 90% correct) do better than those who do not. Noted that within these classes is that students who mastered the assignments exhibit less knowledge decay than their peers leading to the conclusion that e-homework is a valuable asset to learning chemistry. The results also indicate that students' content retention of those who experience e-homework is improved over students who did not use the e-homework available by an average of 15% as scored on an ACS standardized exam given to students the following semester.

Keywords: general chemistry, ICT tools (e-homework), knowledge decay, content retention

1 INTRODUCTION

> *Without continual growth and progress, such words as improvement, achievement, and success have no meaning. -Benjamin Franklin, ca. 1780s*

The topics typically found in first-semester general chemistry (gen chem I) that need to be mastered have not significantly changed in over 15 years (Demirci, 2010), but the tools available to assist students in learning this content have. This broad-based case study began in 2004 and has resulted in data collection from almost 2,000 students. According to the Unified Learning Model (ULM), students are most likely to succeed when they have the appropriate academic background, and are motivated and engaged to progress with the course material at hand (Shell et al., 2010). Most of the students enrolled in these classes have met or exceeded the course prerequisites by having completed at least one course in high school chemistry and are deemed ready to enroll in pre-calculus. Assuming that admission requirements of the university have been met, it is now up to the professor to deliver a course designed to engage and motivate students to succeed.

This study was undertaken because of a desire of the author to lower the DFW rate (grades of D, F or withdrawals) of the students in her classes. With the advent of new Information and Communication Technology (ICT) tools to provide electronic homework (e-homework) systems via the Internet, and the promise to engage and motivate the students, the case study was initiated. The central question was determined to be: Are these ICT tools going to engage and motivate students to an appropriate level for grades of A, B, and C (indicative of success rate) in gen chem I to be increased? This case study evaluated 1,947 students who used 7 different e-homework systems over a span of 14-semesters. The overall students' success rate prior to the implementation of the ICT tools was about 53% for this gen chem I course taught by the author, and by the end of study, the success rate had unfortunately only climbed to 54%—not sufficient enough to warrant the extra monetary outlay by the students.

However, several lessons were learned from this study. Interesting was students' response to the first question on the final exam regarding if the e-homework system they just experienced should be continued the following semester. Of the 1,090 students who expressed an opinion, 70.7% felt as though the e-homework had been valuable enough to them that it should be continued the following semester. Figure 1 shows a breakdown by each of the systems used. The left bar (striped) is reflective of an interactive e-textbook (*OWLBook* by Vining) that was used in the final semester of this study. Students overwhelmingly (91.1%) agreed that its use should be continued. The remaining bars (solid colors) are the response percentages of each e-homework system used indicative of the students' agreement that the use of the targeted system should be continued. The OWL homework system was used together with the *OWLBook*, so the students were queried separately about its continued use outside the use of the e-textbook. In this part of the study, only OWL and Sapling homework systems exceeded a 70% positive response rate supporting their continued use. Student acceptance of any e-homework system is of utmost importance, because without engagement, learning from the e-system is in jeopardy.

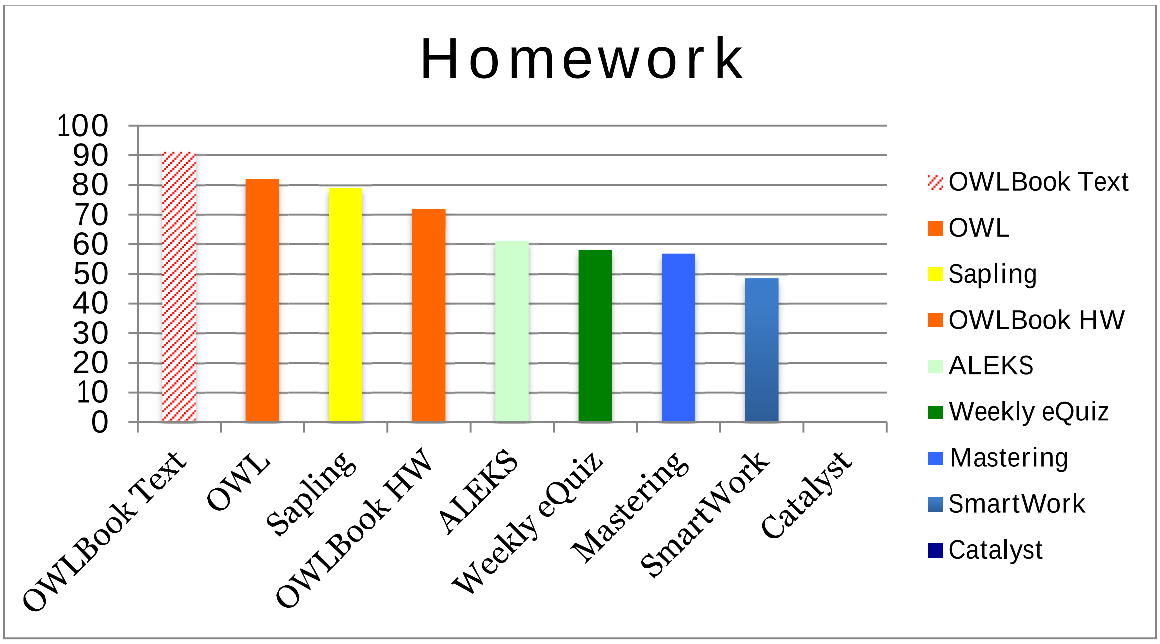


Figure 1. Response percentages to the question asked on the final exam about whether or not the use of electronic homework should be continued. The striped bar concerned the continued use of the e-textbook (*OWLBook*) by Vining (Cengage publishers, 2012). The solid bars are for the various e-homework systems evaluated. The use of Catalyst was discontinued during the semester, so the question about continuing was not asked on the final exam. All e-systems are commercially available except for the Weekly eQuiz that was developed by the author. See Table 1 for further details. (HW = homework)

Class Structure. The value of this research is not limited simply to students' opinions. All of the courses over the eight-year period were taught by the same professor using the same reference textbook (Moore, Stanitski and Jurs, *Chemistry: The Molecular Science*) with the same lecture content in classes that were taught on a Tuesday/Thursday weekly schedule at 0800-0920. Each large-group lecture class (n = 100 in fall semesters and n = 300 in the spring semesters) offered four instructor-developed semester exams and a final exam that composed about 70% of the course grade. The e-homework score was based on the percentage of correctly completed problems that contributed about 17% to the course grade and the remaining 13% was from in-class quizzes and assignments. The questions asked of students on the exams were of the open-ended variety with only an occasional multiple-choice question. Partial credit on most of the problems solved could be received with the majority of the credit awarded to the solving process and not the correct answer. The variable of this case study was the e-homework system chosen by the professor. In the fall semesters seven section of gen chem I were offered, but only one section in the spring semester. Therefore, in the fall semesters, students had a choice of which section to attend. The only professor to require students to complete online homework assignments is the author of this study except for one semester when another professor joined her; as a consequence, this gave students six "escape" (Gates, 2008) sections (i.e., six sections in which to enroll that did not mandate e-homework as part of the course's final average). The spring semester course was considered to be off-sequence, and it was highly possible that the students were either weak in mathematics skills and therefore had delayed their enrollment or they had not been successful in the fall semester and were retaking the course.

See Table 1 for the identification of the seven commercial e-homework systems (in alphabetical order) evaluated and in which semesters they were used.

Table 1. Commercial e-Homework Systems Evaluated

e-System	Publisher	Semester Used
Assessment and **LE**arning in **K**nowledge **S**paces (**ALEKS**)	UC Regents, ALEKS Corp; in 2013, the ALEKS Corporation was acquired by McGraw-Hill	Spring 2009, Fall 2009
Catalyst	WileyPLUS, John Wiley & Sons	Spring 2008
MasteringChemistry	Pearson	Fall 2007
Online **W**eb-based **L**earning (**OWL**)	Brooks/Cole-Cengage Learning	Fall 2005, Spring 2006, Fall 2006
OWLBook	Now *General Chemistry* with MindTap Chemistry	Spring 2012
Sapling Learning	Acquired in 2012 by Macmillan Science and Education	Fall 2010, Spring 2011
SmartWork (**SW**)	W.W. Norton & Company, Inc.	Fall 2008

2 Methodology

In this study content *mastery* is defined as correctly completing at least 90% of the assigned homework generated by the e-homework system chosen for a particular semester. According to Bunce, VandenPlas, and Soulis, *knowledge decay* is forgetting what has been learned and occurs within 48 h following the initial learning experience (2011). In reality, there may be as many as 10-14 days (well more than 48 h) between the last semester exam and the time the final exam is administered. In light of this situation, content retention of students who did and did not participate in e-homework assignments and how much these students retained by the following semester (over a month) were evaluated.

> *Research question:* What performance outcomes will the use of e-homework by general chemistry I students generate as to their knowledge decay and content retention when mastery is attained?

One of the advantages to using e-homework is that students who attain mastery of their e-assignments (≥ 90% correct) performed better than the students who do not attain the 90% level of correct responses. As displayed on Table 2, for every exam the students who mastered the assigned OWL homework outperformed students who got less that 90% of the assignments correct. On the first exam, a few students had yet to register for the OWL e-homework and on the average failed exam 1 (54.0%). By the end of the semester, the performance difference was two letter grades (F to C) on the final exam, and when all aspects of the course were included (i.e., quizzes, classwork, exams, and e-homework scores) students who mastered their homework outperformed those who did not by over two letter grades (23 percentage points.) Similar outcomes were reported for the other e-homework systems used as well.

Table 2. Effect of Using OWL as e-Homework System*

Percentage Completed	≥ 90%	< 90%	Not registered
	Average grade (%)	Average grade (%)	
Exam 1 (n = 94)	77.1	63.3	54.0%
Exam 2 (n = 82)	75.0	59.3	
Exam 3 (n = 72)	77.4	59.1	
Exam 4 (n = 62)	77.7	59.1	
Final Exam (n = 68)	73.6	49.9	
Final course grade for the completers (n = 72)	89.3	66.3	

*Typical example of how e-homework helps students' overall performance on exams. Other systems performed similarly. (Overall class average = 74.8%.)

Even though only the use of OWL e-homework is highlighted in Table 2, the other systems used performed similarly (see Table 3) when averages of the students who mastered their homework were compared to those who achieved at a level of less than 90%. Overall the best performer was Sapling Learning where the results indicate an almost 30-percentage point difference between the two groups.

Table 3. Comparison of Course Averages Based on Mastery of e-Homework

e-System	Number (less W)	≥ 90% average	< 90% average	Change
MasteringChemistry	63	87.4	69.9	17.5
OWLBook	252	85.3	63.8	21.5
OWL	251	85.3	61.7	23.6
Catalyst	123	95.3	71.0	24.3
SmartWork	151	96.0	67.8	28.2
ALEKS	314	93.0	64.6	28.4
Sapling	364	88.9	59.5	29.4

Knowledge Decay. Knowledge decay begins within only a few hours of when students learn the content (Bunce, VandenPlas, & Soulis, 2011). The final exam schedule is published by the university. This schedule separates the last class meetings and the final exams by several days in order to give students time to prepare for their culminating exams. As displayed in Table 4, knowledge decay is apparent. By comparing the four semester exam averages to the final exam scores, the overall change was about a 2-point decrease. Of interesting note is that for almost 2,000 students the weaker the student, the larger the percentage points indicative of knowledge decay. Notice in Table 4 that the change trend increased as the letter-grade performance decreased. Of more interest are that the difference between exam averages and final exam scores for the A and B-grade groups were much smaller than those for the C, D, and F groups and that the knowledge decay of the B-grade group was more than twice that of the A-grade group.

Table 4. Knowledge Decay (Semester Exam Average vs. Final Exam Score) (n = 1,939)

Grade	Number (%)	Exam Average	Final Exam Score	Change
Overall		**65.7**	**63.8**	**-1.9**
A+ (exempt)	88 (4.5)	95.9		
A	259 (13.4)	87.8	86.1	-1.7
B	340 (17.5)	76.7	72.9	-3.8
C	186 (18.6)	67.0	61.8	-5.2
D	266 (13.7)	56.9	51.4	-5.5
F	176 (9.1)	42.2	36.4	-5.8
F (no show)	208 (10.7)	32.0		
W	241 (12.4)			

Plotting the averaged semester exam scores against the corresponding final exam percentage for each e-homework system can be seen in Figures 2-6. The graphs are all quite similar, except for a slight variation in Figures 5 and 6 where Sapling (Figure 5) and ALEKS (Figure 6) crossed close to the B-grade level. It is possible that this observation indicates that both Sapling and ALEKS may help the best students retain the necessary content to a greater extent than the other systems evaluated (i.e., OWL, OWLBook, and MasteringChemistry) in these classes.

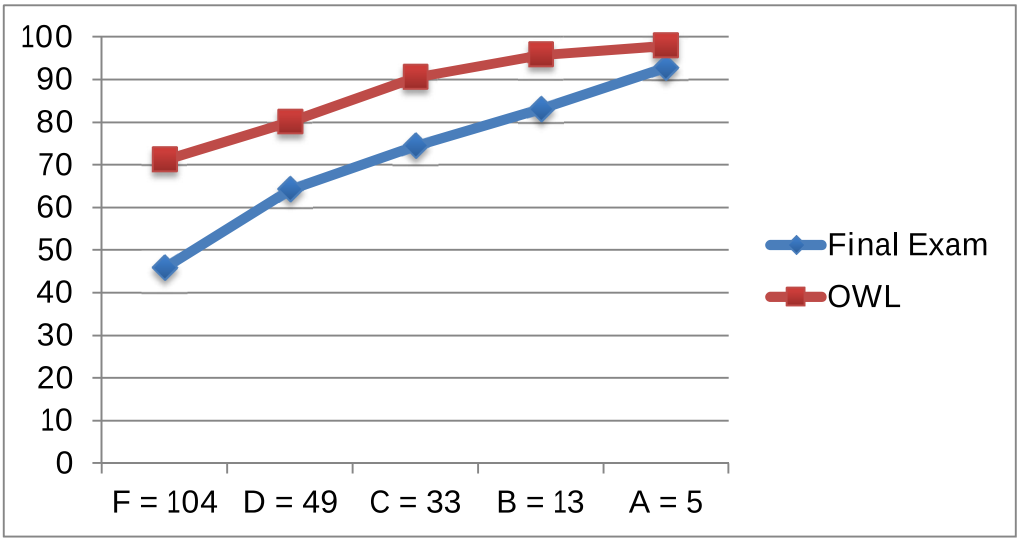


Figure 2. OWL comparison of semester exam averages and final exam scores (n = 204).

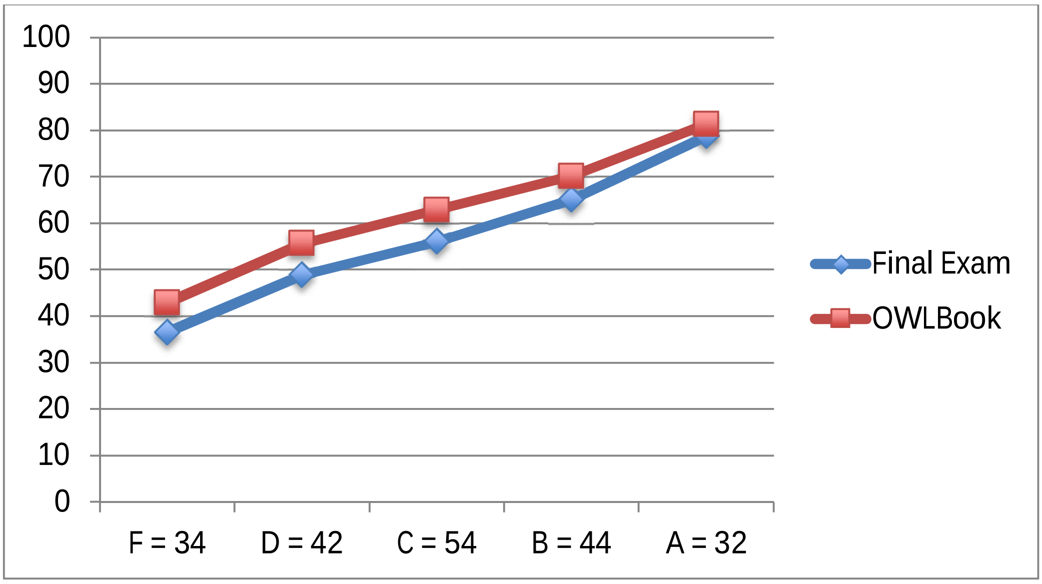


Figure 3. OWLBook comparison of semester exam averages and final exam scores (n = 206).

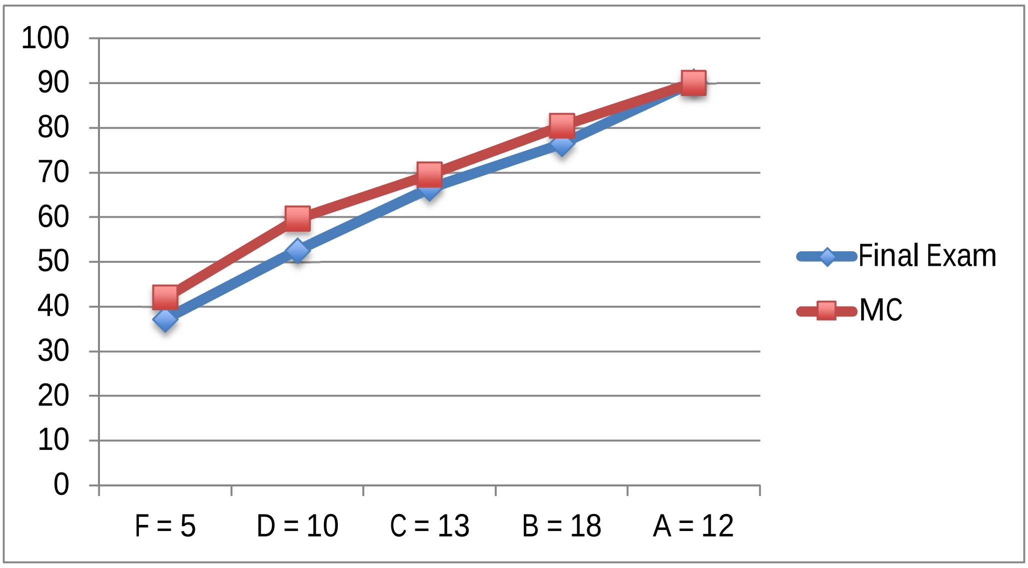


Figure 4. MasteringChemistry comparison of semester exam averages and final exam scores (n = 58).

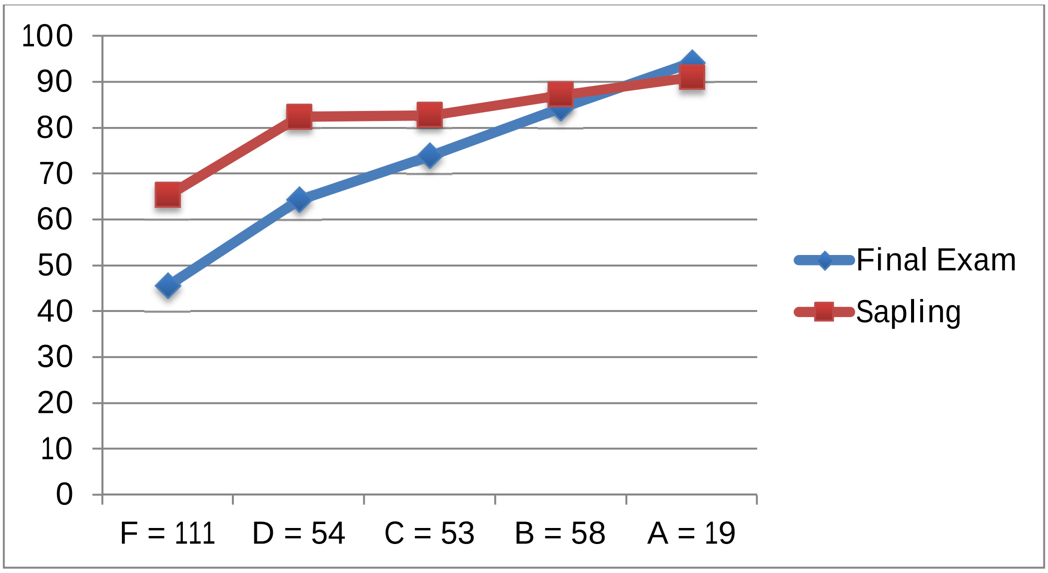


Figure 5. Sapling comparison of semester exam averages and final exam scores (n = 295).

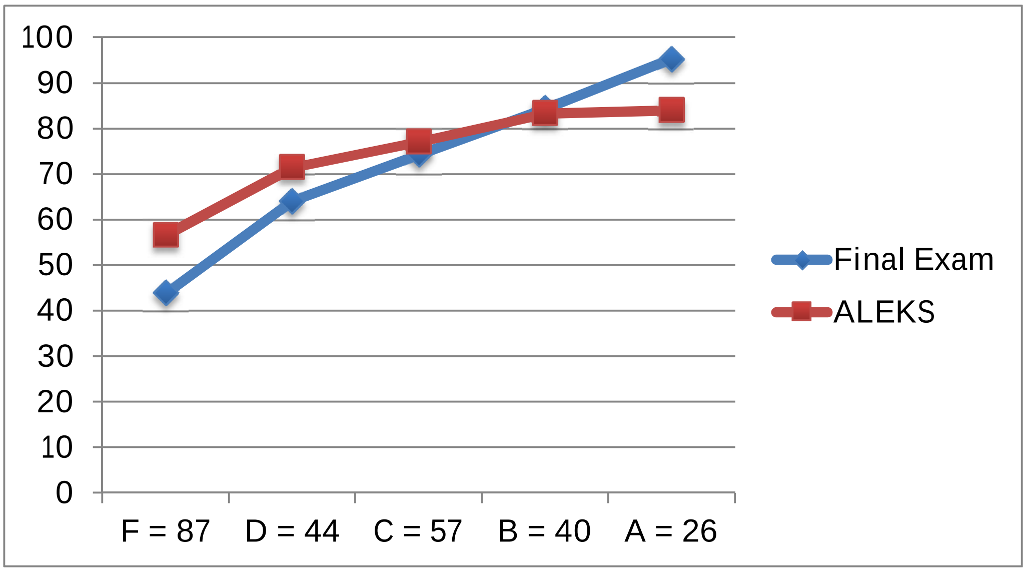


Figure 6. ALEKS comparison of semester exam averages and final exam scores (n = 254).

Content Retention. Content retention is very important to students' success as they progress in the general chemistry sequence to the second semester. For three semesters (two where OWL was used and one where the students used MasteringChemistry), a delayed post-test was given to the students who enrolled in the laboratory course for general chemistry II. Data were collected from all the gen chem II students who had been enrolled in any of the gen chem I sections and decided to continue to the next general chemistry course. In this evaluation the results indicate (see Table 5) that students who had experienced e-homework outperformed students who had not used the e-homework available by 15% on the average as determined by student performance on an American Chemical Society (ACS) standardized exam. Due to peer pressure from other faculty who had not chosen to use e-homework in their classes, this aspect of the study was discontinued. The major lesson learned is that if you are planning on adopting e-homework to be used in your classes and there are multiple sections, please, make the adoption course-wide. Providing students with escape sections is not good protocol.

Table 5. Delayed Post-Test Results on ACS Exam*

	Used e-Homework	Did not use e-Homework
OWL	24.2	19.7
OWL	27.8	20.2
MC	27.2	21.3

*Maximum score on exam = 40 points.

Three e-systems were used for both fall and spring semesters (see Table 1). Figures 7 and 8 compare the percentage of students who failed to correctly complete at least 90% of the required homework (Figure 7) and those who correctly completed 90% or more of the required homework (Figure 8).

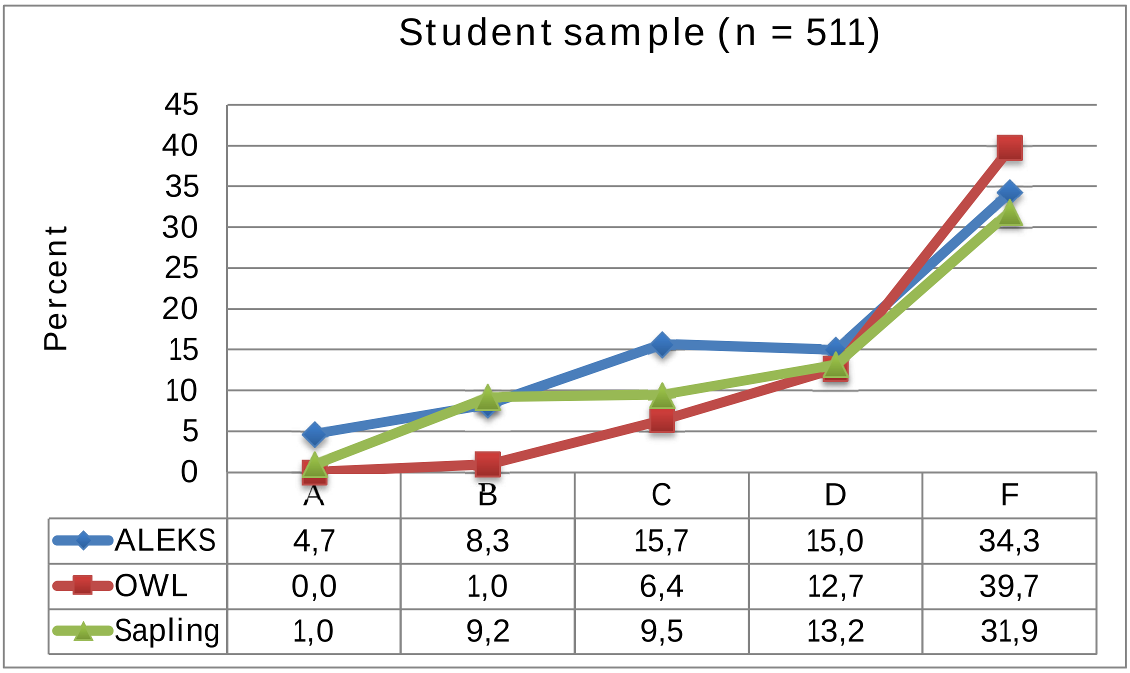
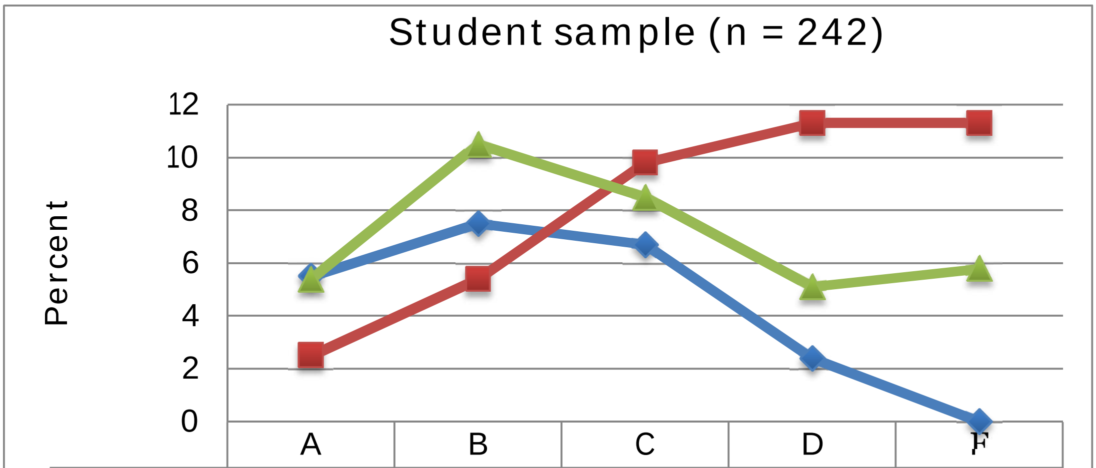


Figure 7. Percentage of students who correctly completed < 90% of the e-HW assigned on ALEKS, OWL, and Sapling and their grade on the final exam.



	A	B	C	D	F
ALEKS	5,5	7,5	6,7	2,4	0,0
OWL	2,5	5,4	9,8	11,3	11,3
Sapling	5,4	10,5	8,5	5,1	5,8

Figure 8. Percentage of students who correctly completed ≥ 90% of the e-HW assigned on ALEKS, OWL, and Sapling and their grade on the final exam.

As can be seen in Figure 7, the trends were basically the same for all three e-homework systems. If students did not adequately complete the assigned e-homework, the chances of being unsuccessful in the class (i.e., making a grade of D or F) escalated to almost 50% of the total number of students (n = 511). However, in Figure 8 (n = 242), ALEKS and Sapling presented similar trends that would be consistent with what one would expect: fewer students would make D's or F's, if they completed 90% or more of their e-homework. For ALEKS no student who was successful on the e-homework, failed the final exam and for Sapling less than 6% failed the final exam. However, OWL's data were interesting. It appears that even when 90% or more of the OWL homework was correctly completed, a large percentage of these students were not successful on the final exam (grades of D or F).

3 Conclusions

First-semester general chemistry is a gateway course to the future for many students. The content of general chemistry may not have changed significantly in a number of years and probably will not any time in the near future, but instructors of general chemistry need to be willing to adapt to changes in the use of the ICT tools available. "Calcified" faculty exist, as do naysayers, and they always will, but as the ICT tools available evolve, we need to be willing to adapt to their advantages. In some aspect it is easier not to ask students to do e-homework because your withdrawal rate will probably increase (see Table 4) as mine did, but overall at least my DFW (students who received grades of D, F, or withdrew from the class) stayed fairly constant and consistent with the DFW rate of prior semesters before the institution of e-homework. Presenting these data to students (and your colleagues) and encouraging them to complete the assigned e-homework at the mastery level will without a doubt serve them well.

The following are lessons learned from the evaluation of these data:

1. Overall, the student success rate (grades of A, B, and C) is not significantly impacted by the use of doing e-homework; there are students who refuse to do assigned work.
2. On the average most students see the value of continuing with the use of e-homework the following semester.
3. Students who do their homework do better than those who do not.
4. Students' knowledge decay is less for those who have experienced e-homework than for those who have not.
5. Students who experience e-homework and continue with the second general chemistry course sequence have more content-knowledge retention than students who do not experience e-homework.
6. In this study Sapling and ALEKS performed the best of the e-systems evaluated, but probably helped the better students more than those of lesser ability.

The dictionary is the only place that success comes before work. Hard work is the price we must pay for success. I think you can accomplish anything if you've willing to pay the price.
-Vince Lombardi, ca. 1960

Note

The author declares no competing financial interest.

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