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Case Study Using Online Homework in Undergraduate Organic Chemistry: Results and Student Attitudes

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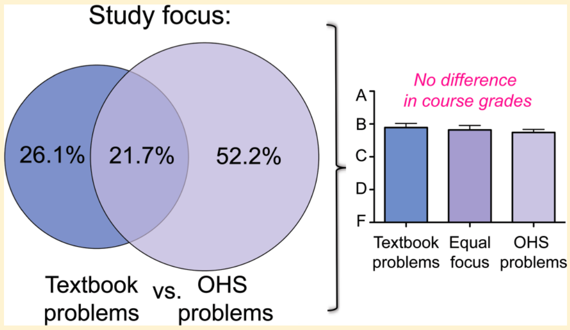
ABSTRACT: Managing student needs for effective learning in a large-enrollment, introductory organic chemistry course can be a challenging task. Because instructor time is at a premium, it is imperative to find resources that engage the students in active learning and provide them with feedback about their understanding of course content. Appropriately designed online homework systems can provide this level of engagement. Here we describe our experience with using the Sapling Learning online homework system in an organic chemistry course for prepharmacy majors. Based on the literature describing the effectiveness of online homework in general chemistry and other courses, we hypothesized that student engagement in the online homework would be associated with students' performance in the course, but that studying with the textbook problems would provide a greater benefit because the material was more sophisticated. We found that engagement in using the system was positively correlated with course grade, and that student perceptions of the system were overwhelmingly positive. Surprisingly, we also found that spending more time studying with the problems in the textbook was not associated with significantly better performance than using the online homework system alone. We speculate that this is because the immediate feedback given by the online system more effectively reinforces the topics. Furthermore, we found that despite the perceived utility of the system and its relationship to final course grades, students still seemed to require an extra-credit incentive to incorporate the use of the system into their study habits. This case study suggests that learning reinforcement through real-time feedback and extra credit (or other points-based) incentives to motivate participation are important components of achieving student benefits from an online homework system.



KEYWORDS: *Second-Year Undergraduate, First-Year Undergraduate/General, Chemical Education Research, Organic Chemistry, Internet/Web-Based Learning, Testing/Assessment*

FEATURE: Chemical Education Research

■ INTRODUCTION

Modern undergraduate chemistry education at most institutions involves several types of multimedia interactions, and many efforts to study their effectiveness have been put forth. In particular, the benefits of online homework systems (OHS) in first-year-level general chemistry courses have been well established and thoroughly reviewed.[1] Software such as the WileyPlus and Mastering Chemistry systems[1] and Web-based worked example systems[2] have been shown to provide advantages for student learning and performance. The effects of online homework systems in STEM (science, technology, engineering, and mathematics) courses have been extensively researched and reviewed. These systems are thought to function by promoting several of the key principles of good practice in undergraduate education.[1,3] The specific key principles addressed by OHSs include encouraging active learning, giving prompt feedback, and emphasizing time on task. The automated way that online homework systems provide these advantages is particularly valuable in large-enrollment introductory courses, in which instructor time is at a premium and student need for additional help is high.

Organic chemistry courses, on the other hand, have been slower to incorporate OHSs—possibly because of the functional requirements for communicating and demonstrating organic chemistry principles. These principles include the ability to accurately draw and interpret chemical structures and indicate reaction mechanisms using the curved arrow notation, and were not addressed with early systems such as the WE_LEARN system.[4] These early online organic chemistry systems tended to focus on multiple choice, true−false, short-answer and fill-in-the-blank type questions. More recent software packages have incorporated tools for conveying these concepts and drawing structures, including the EPOCH/ACE Organic system[5] and the curved arrow neglect (CAN) approach,[6] which focuses on reaction intermediates, but ignores curved arrow notation itself. The Synthesis Explorer program developed at University of California−Irvine[7] and a recently introduced OHS from Sapling Learning,[8] which includes actual curved arrow notation functionality as well as the other traditional online formats for answering questions mentioned above, address these concepts with more sophisticated functionality.

These concepts of structure, molecular interactions, and reactions underlie the "language" of organic chemistry, and we view them as essential to mastering the basics that go on to contribute to a comprehensive understanding of biochemistry and pharmacology—principles that are, in turn, essential to a thorough training program in biology and medicine (as discussed in the recent report from the American Association of Medical Colleges *Scientific Foundations of Future Physicians*).[9] By improving student learning and engagement on these fundamental organic chemistry concepts, these systems could be extremely helpful in addressing the student achievement gap between general chemistry and organic chemistry,[10] particularly in biomedical science-focused majors and preprofessional programs in which first-semester organic chemistry is often perceived as a "weed-out" course.

Accordingly, we set out to study the effects and student perceptions of an OHS, the Sapling Learning system,[8] implemented in our first-semester organic chemistry course targeted toward prepharmacy undergraduates. The purpose of this study was not to compare diverse online homework systems, but rather to test whether the particular system that we thought offered potential for benefit in fact provided enhanced learning outcomes for organic chemistry (typically considered to require higher-order learning and problem solving).[10] Two cohorts were analyzed—one for detailed examination of the effects of the OHS, and the other to compare self-motivation for engaging in the system with the first cohort. We hypothesized that participation in the online homework assignments would be associated with better course performance, but that working the problems in the textbook would have the strongest correlation with course grade. We tested this hypothesis by correlating student engagement in the online homework system with final grades in the course, both self-reported and actual, and comparing the effect of online homework system engagement versus textbook problem engagement (as self-reported by students). We also hypothesized that a point incentive via extra credit was necessary to motivate students to engage with the online homework.

■ MATERIALS AND METHODS

Student Population

Cohort A (prepharmacy organic chemistry class for Fall 2009, MCMP204, first semester, N = 243, and Spring 2010, MCMP205, second semester, N = 200) was analyzed in detail for OHS engagement and class performance. Cohort B (prepharmacy organic chemistry class for Fall 2010, MCMP204, first semester, N = 226, and Spring 2011, MCMP205, second semester, N = 182) was not included in the analysis of OHS engagement and class performance. Students in Cohort A were given extra credit for OHS use in both the first- and second-semester courses, while students in Cohort B were only given extra credit for OHS use in the first semester and not in the second semester. Students in both cohorts were typically second-year students who had previously completed general chemistry (in which the Online Web Learning, or OWL system was used) and whose GPA was ≥2.5 (average GPA for Cohort A = 3.529, SD = 0.4260; for Cohort B = 3.504, SD = 0.4340). A Mann–Whitney test comparing GPA distributions between the two cohorts showed that they could be considered equivalent for the purposes of our performance comparisons: p = 0.6915, indicating no significant difference between the incoming GPA distributions.

Online Homework System

The online homework system from Sapling Learning[8] was used. A set of assignment modules (15 total) was custom-built from this OHS database to fit the MCMP204 curriculum by one of us (L.L.P.) in collaboration with a teaching assistant staff member from the OHS. The assignments were organized approximately by lecture topic and were associated with one or more textbook chapters, and due dates were set to a timeline two weeks postcompletion of a given topic or chapter in lecture. Students were given three tries per question, with progressively decreasing credit (loss of 5% per try). Use of the system was optional, with extra credit given (for both cohorts of MCMP204) to a maximum of 50 points (out of 1200 total points for the course), which had the potential to add at most 4.2% (or 0.28 on a letter grade scale in which each grade level represents ∼15%) to students' final course grade (considered a trivial amount of benefit for online homework completion points alone). Students were informed at the beginning of the course that the OHS would typically test the "basics" and that they must spend significant energy and time on practicing the problems in the textbook, particularly the end-of-chapter problems that integrate multiple topics.

Course Performance Assessment

Student performance in the course was evaluated using three hour-long exams (worth 100 points each in the final grade), eight quizzes (worth 150 points total in the final grade), and a final exam (worth 150 points in the final grade). The total of these was scaled by 150% for a total possible of 900 points. Points from the laboratory (300 possible) were added for a course total of 1200 points. Extra-credit points available from all sources (90 possible, with 50 possible points coming from the OHS) were then added. Students were organized into groups and allowed to discuss the more difficult questions on the hour examinations at the beginning of each examination, but students had to answer these questions individually. The final exam also allowed the option of "resurrecting" any previous poor performance; that is, the final examination grade could replace any or all of the hour examinations and quiz totals that had a lower percentage score. The final examination was completely individual, and did not incorporate the group-discussion phase. The content of the exams and quizzes was not drawn specifically from the OHS (in order to avoid biasing exam performance toward those who had used the OHS), with one of us (G.M.L.) writing most test and quiz questions without having viewed the OHS, and one of us (L.L.P.) avoiding conscious quoting of OHS questions on quizzes and exams—with the caveat that some of the OHS content was designed by Sapling Learning staff based on the textbook used in the course, authored by one of us, G.M.L.

Assessment of OHS Engagement

To quantify the level of engagement in the OHS, we devised a scoring system that we termed the Sapling work ethic (SWE), which was calculated from student responses to a survey question on their use of the system and an assessment by the instructor of actual OHS completion and score. Student-reported SWE scores from the survey question were classified as follows: 1, used for the entire semester; 2, used for most of the semester; 3, used for about half of the semester; 4, used for a small part of the semester; and 5, subscribed but did not use.

Thus, lower numbers indicate greater OHS engagement. Instructor-assessed SWE scores were classified using analytics data from the OHS as follows: 1, completed at least 14 out of 15 assignment modules (>93%); 2, 93% ≥ assignments completed ≥ 80%; 3, 80% > assignments completed > 50%; 4, 50% ≥ assignments completed ≥ 20%; and 5, assignments completed < 20%.

Surveys

The research on surveys and course assessment data used for this study was classified as Category 1 exempt by the Purdue University Institutional Review Board for human subjects research (exempt protocols #0910008516, #1112011642 and #1202011822, approved 10/17/2009, 12/19/2011, and 02/07/2012). The surveys on the OHS were administered as part of the overall course evaluation survey, which was taken voluntarily (incentivized via a 6 point/0.50% bonus for completion) by students in the last few weeks prior to the final exam, and had a 93.8% response rate overall. Students were asked specific questions regarding the OHS, including their self-assessment of their use, perception of difficulty of the questions and perception of utility for both mastering the material and studying for exams. Upon completion of the final exam and calculation of student final grades, OHS performance data and course grade data were linked before deidentifying the data set for further analyses. While an individual's responses were linked throughout the survey question data, survey response data remained deidentified to the instructors throughout; thus, correlations between grades and perceptions are based solely on student self-reporting of expected grade in the survey. We found, however, that inferences can be made based on the relationship between actual grades and self-reported expected grades (as described in the Results section).

Statistical Analyses

The relational inquiries of the student responses were carried out with DBASE III+. Quantitative and statistical analyses were performed using SPSS or GraphPad Prism. Statistical tests for significance relied primarily on independent-samples non-parametric *t*-tests, with two-way ANOVA used where mentioned and significance for each method of analysis reported as *p* values.

■ RESULTS

OHS Engagement Is Associated with Improved Course Performance

Final course grades (expressed as a percentage of total points achieved, minus the laboratory portion) for Cohort A were tabulated and compared with OHS performance grades (also expressed as a percentage of total points achieved). We found a moderate positive correlation (r^2 = 0.295) between OHS performance and overall performance in the course (Figure 1). However, by analyzing self-reported and empirically determined engagement in the OHS material (SWE), we found additional differences that helped explain the scatter shown in the plot in Figure 1. Table 1 describes the correspondence between the students' self-reported SWE scores and our empirical SWE estimates derived from the OHS data in which the students' efforts on the assignments were recorded. These OHS data allowed us to see which assignments had been worked but not completed, which likely explains the differences between the number of students who report that they "used [it] for the entire semester" (SWE score of 1) versus those who actually completed >93% of the assignment content. Overall, we found that of students who subscribed to the OHS, 83.3% (N = 180) engaged actively in using the system (SWE scores of 1 or 2), whereas the remaining 16.7% (N = 36) described and demonstrated less engagement (SWE scores of 3, 4, or 5).

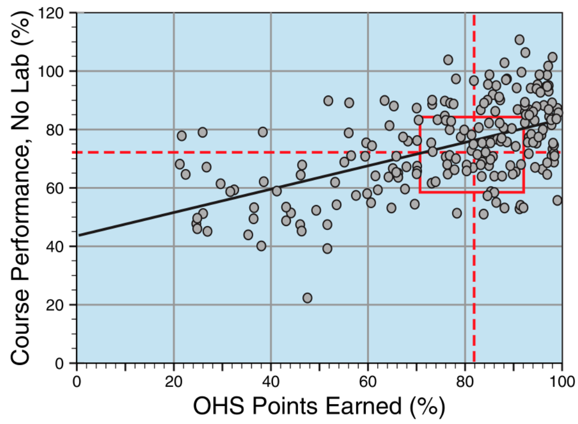


Figure 1. Correlation between course grade performance (minus the lab portion) and online homework system (OHS) points for Cohort A (N = 243). The solid line represents the regression for the relationship between the two (r^2 = 0.295). The intersecting dashed lines indicate the mean for each axis (82% for OHS points and 72% for course grade performance). The red box indicates the standard deviation for the two means. A substantial number of students clustered in the better-than-average quadrant defined by each mean (upper right), illustrating the association between OHS engagement and class performance.

Table 1. Comparative Scores for Engagement with the Online Homework System

	Distribution of Students by SWE Score, *N*		
SWE[a] Scores	Students' Self-Report	Empirical Data Estimate	Difference[b]
1	145	118	27
2	35	51	(16)
3	14	20	(6)
4	20	22	(2)
5	2	3	(1)
Total[c]	216	214	2

[a]Sapling work ethic (SWE) scores quantify the use of the online homework system. [b]Spearman correlation coefficient = 1.0; p = 0.0083. [c]Total difference from course enrollment accounted for by other categories, e.g., "did not subscribe".

Students in Cohort A were also asked in the survey to self-report their grade. In the course syllabus, they were provided with a formula that they could use to estimate their grade using their quiz and exam grades as they accumulated during the course of the semester, and they were reminded of this formula in the survey question, so we believed that their self-reported grades would be accurate enough to use for analyzing the relationships between student survey responses, SWE scores, and grades using the deidentified survey data. To confirm this, we compared the relative numbers of grades as self-reported with those calculated from actual course performance measures (Table 2). Using statistical comparisons, good correspondence was found between the number of self-reported and actual grades in each bracket, giving us reasonable confidence that we could use these self-reported grades for analyses of survey data.

Once we had established that self-reported grades would provide an accurate estimate of actual grades in the course, we analyzed the differences between self-reported and empirically

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Table 2. Comparative Distribution of Student Grades, Reported versus Actual

Grade	Reported Student Grades[a]	Actual Student Grades	Difference in Grades, %[b]
A	36	28	(8)
B	102	106	(2)
C	69	70	1
D	16	7	(8)
F	5	17	12
Total	228	228	100.0

[a]Grades reported by students on course evaluation survey just prior to final exam; actual grades do not include points directly from the online homework system extra credit. [b]Spearman correlation coefficient = 0.9; p = 0.0417.

determined SWE scores and self-reported and actual grades for Cohort A (Table 3) by OHS engagement. Prior to the final exam, we found a statistically significant difference (mean 0.71 letter grade points, $p < 0.005$) in self-reported grades between students who actively engaged in the OHS (SWE scores of 1 or 2) and students who did not (SWE scores of 3, 4, or 5; see Table 3). The difference was also apparent between empirically determined SWE scores and actual grade percentages, with a mean difference of 10.5 grade percentage points between the two groups (Table 3), which corresponds to a 0.71 letter grade (LG) point difference, in strong agreement with the self-reported data. Even more striking was the difference in actual grade percentage points totaled after the final exam, which included the extra credit points contributed directly from the OHS performance percentage, corresponding to a 5.6%/0.37 LG maximum, a 4.5%/0.30 LG average based on the course total, not including laboratory points. As seen in Table 3, the mean grade percentage difference between OHS-engaged (SWE scores of 1 or 2) and nonengaged students (SWE scores of 3, 4, or 5) was 18.6% ($p < 0.005$), which corresponds to just over a full letter grade advantage for the OHS-engaged students (1.24 LG) and nearly that even when corrected for the contribution of the OHS extra credit points (0.87 LG).

Time Spent on Textbook Problems Did Not Appear To Enhance Success

One potential explanation for the association between OHS engagement and higher grades is the overall stronger motivation and work ethic exhibited by high-performing students.[11] Therefore, we examined Cohort A students' self-reported study habits with the aim of "normalizing" the results to overall work ethic and motivation. Students were asked in the survey whether they spent a higher proportion of their out-of-class study time on the OHS problems, the end-of-the-chapter textbook problems, or an equal amount of time on both (Figure 2). We analyzed these data for students with SWE scores of 1 and 2 (N = 180), and found that despite a slight trend toward better grades, students who self-reported spending a substantial amount of time on the textbook problems (N = 47, 26.1%) or even an equal amount of time on those problems (N = 39, 21.7%) did not have substantially nor significantly higher grades than those who reported spending most of their time on the OHS problems (N = 94, 52.2%; see Table 4). This was especially surprising given the inference that students with a SWE score in this top bracket (indicating they spent substantial amounts of out-of-class time

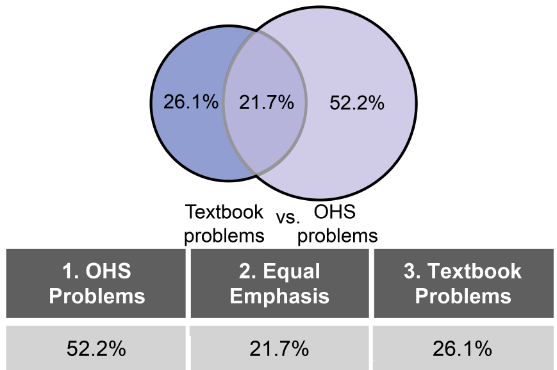


Figure 2. Self-reported study focus for highly engaged students (SWE scores ≤ 2 for use of an online homework system, OHS; N = 180).

Table 4. Mean Self-Reported Grades for Highly Engaged Students by Study Tool Emphasis

Study Tool Emphasized	Mean RG ± SD for SWE 1 or 2[a]	Difference (Mean)	p Value[b]
OHS[c]	2.74 ± 0.92	(0)	—
Equal[d]	2.82 ± 0.84	0.08	—
Textbook[e]	2.89 ± 0.88	0.15	0.37

[a]RG (reported grade): A = 4, B = 3, etc. SWE (Sapling Work Ethic) scores range from 1 to 5. [b]This p-value is for the comparison of the grades obtained by students emphasizing the textbook over the OHS. [c]Emphasis on mainly online homework system (OHS) problems is 52.2% fraction, N = 94 (fractions from Figure 2). [d]Emphasis equally on both OHS and textbook is 21.7% fraction, N = 39 (fractions from Figure 2). [e]Emphasis on mainly textbook problems (26.1% fraction, N = 47) (fractions from Figure 2).

Table 3. Distribution Comparison of Student Grades Prior to Final Exam, Reported versus Actual

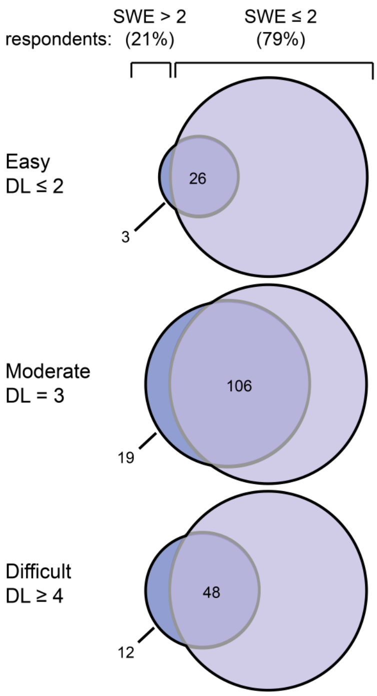
	Self-Reported: Expected Grade and SWE Rankings (Prior to Final Exam)[a]	Actual: Calculated Final Grade and Empirically Determined SWE Rankings (Prior to Final Exam), %[b]	Actual: Calculated Final Grade and Empirically Determined SWE Rankings (after Final Exam, including OHS Points), %[c]
Mean ± SD for SWE of 1 or 2	3.07 ± 0.71	71.4 ± 11.3	77.2 ± 13.6
Mean ± SD for SWE of 3, 4, or 5	2.36 ± 0.83	60.9 ± 11.1	58.6 ± 14.8
Mean Difference	0.71 ($p < 0.005$)	10.5 (p = 0.0001)	18.6 (p = 0.005)
Change in LG	—	0.71	1.24

[a]Reported grade (RG) values: A = 4; B = 3; etc. This did not include online homework system (OHS) points. SWE (Sapling Work Ethic) scores range from 1 to 5. [b]1 LG = 15%. Letter grade (LG) calculations did not include OHS points. [c]1 LG = 15%. OHS maximum possible addition was 5.6%/0.37 LG; average addition was 4.5%/0.30 LG.

on the OHS material) were likely to have spent an even greater proportion of time on the textbook problems (in order to be able to report that they spent more of their time on the book problems). This suggested that time spent working end-of-chapter problems in the textbook had very little effect on improving grades even for these hardworking students.

Perceptions of Difficulty Level and Usefulness of OHS

Using the survey responses, we also analyzed student perceptions of the difficulty level and the helpfulness of the OHS assignments for Cohort A. The Venn diagrams in Figure 3 show the overlap between SWE scores and student

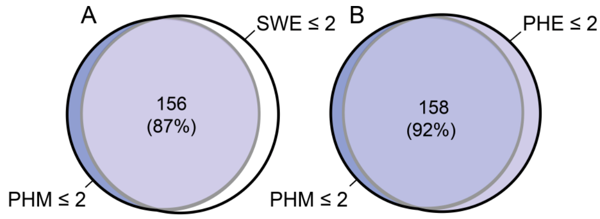


Difficulty Level	*N* (%), SWE > 2	*N* (%), SWE ≤ 2
Easy (DL ≤ 2)	3 (8.8%)	26 (14.4%)
Moderate (DL = 3)	19 (55.9%)	106 (58.9%)
Difficult (DL ≥ 4)	12 (35.3%)	48 (26.7%)

Figure 3. Self-reported difficulty level for all respondents to the survey ($N = 214$). The large circles represent the population of students with SWE scores ≤2) (79% of respondents); the small circles represent populations according to classification of difficulty level. Difficulty level was scored on a scale of 1−5: 1, very easy, 2, easy; 3, moderate; 4, difficult; 5, very difficult. Lighter color circle segments represent students actively engaged in the online homework system (SWE ≤ 2) according to difficulty level, and darker color circle segments represent students with SWE scores >2 (21% of respondents) according to difficulty level.

perceptions. As observed from the larger-sized circles for the "moderate" and "difficult" ratings, overall most of the students found the problems challenging (DL ≥ 3, where DL is the difficulty-level perception, with higher numbers indicating a perceived greater difficulty). Students less engaged in the OHS (SWE scores >2) were slightly less likely to rate the OHS problems as easy (8% of students with SWE scores >2 vs 14% for students with SWE scores ≤2) and slightly more likely to rate them as very difficult (35% for students with SWE scores >2 vs 27% for students with SWE scores ≤2). Figure 3 also shows the relative response populations for the different difficulty classifications. As observed from the increased overlap between the "moderate" and "difficult" ratings and the circles representing the population of students with SWE scores ≤2 in Figure 3, these students tended to describe the OHS problems as being moderate to difficult (86% of total scores of students with SWE scores ≤2). This indicated that the material was targeted at a level that would appropriately challenge students without being too easy or simplistic, yet not be beyond the abilities of most students.

Students in Cohort A also overwhelmingly reported that they found the OHS helpful (Figure 4). More than 80% of survey



Perceived Helpfulness ≤ 2	*N* (%), SWE ≤ 2
Exams	176 (82%)
Mastering material	171 (80%)
Overlap	158 (92%)

Figure 4. Perceived helpfulness of the online homework system (OHS) for mastering the material and for preparing for the exams. Perceived helpfulness was ranked as follows: 1, extremely helpful; 2, helpful; 3, not sure; 4, not very helpful; 5, did not use. Out of the total responding ($N = 214$), 80% of students ($N = 171$) ranked the perceived helpfulness for mastering the material (PHM) of the OHS as helpful or extremely helpful (PHM ≤ 2). For the perceived helpfulness for preparing for the exams (PHE) of the OHS, 82% ($N = 176$) of students ranked it as helpful or extremely helpful for preparing for exams (PHE ≤ 2). Shown is the overlap between (A) PHM of the OHS (PHM ≤ 2, darkest color circles) with SWE scores (white circle); and (B) PHE of the OHS (PHE ≤ 2, medium color circle).

respondents perceived the OHS as helpful for both mastering the material (PHM, perceived helpfulness in mastering the material, with lower numbers indicating higher perceived helpfulness; i.e., learning the course content), and preparing for exams (PHE, perceived helpfulness for exams, with lower numbers indicate higher perceived helpfulness; i.e., course performance). In particular, perceptions of helpfulness in mastering the material were even stronger among students with SWE scores ≤2 (87% of SWE respondents with scores ≤2 vs 73% of all respondents—visualized via the overlap between PHM and SWE in the Venn diagram shown in Figure 4A). Furthermore, there was good agreement between these two perceptions (visualized via the overlap between PHE and PHM in the Venn diagram shown in Figure 4B)—92% of respondents who found the OHS helpful in mastering the material also thought the OHS was helpful in preparing for the exams.

Additional Observations: Relationship between Performance, Collaboration, and Gender

Students were allowed to collaborate in working the OHS problems after the instructor pointed out to them the difference

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between collaboration and copying, and reminded students that they were likely to derive little benefit from the homework if answers were copied. Using survey questions, we assessed whether collaboration on the OHS assignments had an effect on course grade (as self-reported prior to the final exam) for Cohort A. We found that about two-thirds of students worked alone (Figure 5), and that slightly more students with SWE scores >2 worked alone than in those with SWE scores ≤2 (70% vs 64%) (Figure 5); however, this difference was not statistically significant. For students with SWE scores ≤2, the average grade was not affected by collaboration (COL), with each COL bracket exhibiting a mean reported grade of 2.20 (Table 5).

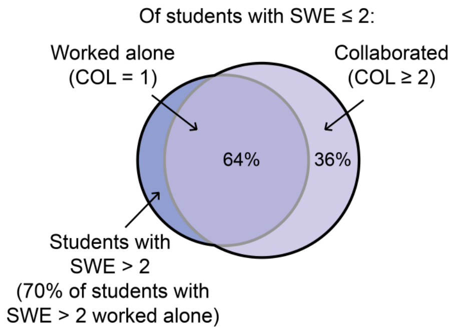

Figure 5. Overlap between levels of self-reported collaboration among students with varying levels of engagement (SWE scores) in the online homework system (OHS). Of students with SWE scores ≤2 (actively engaged in OHS, N = 180), 64% worked alone (collaboration ranking, or COL = 1), and 36% worked with others (collaborated, COL ≥ 2). Of students with SWE ≥ 2 (less engaged in OHS, N = 34), 70% worked alone (as indicated by the portion of the darkest circle on the left that does not overlap with the SWE ≤ 2 population), and 30% worked with others (not shown in this diagram).

Table 5. Comparative Collaboration Rates Overall for Students with SWE ≤ 2

Collaboration Scores[a]	N	Mean of RG ± SD[b]
1	115	2.80 ± 0.88
2, 3, 4	65	2.80 ± 0.89

[a]Collaboration scores indicate a student's degree of collaboration with other students, with 1 designating "worked alone", and 2, 3, and 4 indicating increasing degrees of "worked with others". [b]RG (reported grade): A = 4, B = 3, etc. These data were collected from the survey taken prior to the final exam.

We also examined the correlation between gender and self-reported collaboration for this cohort, and found that female students were more likely to work alone than male students, although this difference was not quite statistically significant (p = 0.0765 according to the Mann−Whitney test). However, there was no additional effect of SWE on the relative numbers of female and male students who worked alone versus those who collaborated (Table 6). Also intriguingly, female students were slightly more likely to subscribe to the system in the first place, with 97% of female students using the system versus 90% of male students; however, this difference was not statistically significant (according to Fisher's exact test). Nonetheless, this seems to be consistent with results presented by Richards-Babb and Jackson[12] in which male students self-reported less positive views toward online homework (even though they experienced greater performance gains from online homework system use) than female students.

Table 6. Correlation of Gender with Collaboration by SWE

	Collaboration Score of 1, %[a]	
SWE Scores[b]	Male Students[c]	Female Students[c,d]
1	50	68
1, 2	57	68
1, 2, 3, 4, 5 (all)	59	69

[a]Collaboration scores indicate a student's degree of collaboration with other students, with 1 designating "worked alone". [b]SWE (Sapling work ethic) scores range from 1 to 5. [c]Gender distribution for class was 37/63% M/F; gender distribution for online homework system adoption was 39/61% M/F. [d]Overall not quite significant difference, p = 0.0765 (Mann−Whitney test).

Effect of Extra-Credit Incentive on Use of the OHS in a Follow-Up Course

By comparing OHS data for Cohorts A and B, we assessed the students' self-reported likelihood and actual follow-through to use the OHS both with and without an extra-credit point incentive (Table 7). In our end-of-course survey from the primary cohort described in this case study (Cohort A), 33% of students reported that they would definitely use the system regardless of extra credit point incentive obtained, while 47% reported that they were not sure. The remaining 20% reported that they would not use the system again. Student follow-through on this attitude was assessed by analyzing the OHS adoption and engagement for the next semester's follow-up course, MCMP205, taught by a different instructor. For Cohort A, the second-semester instructor provided an extra-credit point incentive for use of the OHS that was commensurate with the level offered by us for the first semester. We found that 88% of Cohort A students enrolled in the OHS during the second semester (MCMP205, spring 2010), and 72% of students who enrolled in the OHS had a nonzero score for the majority (defined as >80%) of the assignments, representing 64% of the class overall. For the next year's cohort (Cohort B), however, the extra credit point incentive was only offered in the first semester (MCMP204, fall 2010) and not in the second (MCMP205, spring 2011). For Cohort B, 92% of students enrolled in the OHS during the first semester (MCMP204, fall 2010) and 83% had a nonzero score for the majority of the assignments (similar to Cohort A). Strikingly, however, only 24% of Cohort B students enrolled in the OHS without the extra-credit point incentive, and of those students, only 6% had

Table 7. Comparative Effects of Offering an Extra-Credit Incentive on Students' Enrollment and Participation in the Online Homework System

	Student Cohort A, %		Student Cohort B, %	
OHS Involvement[a]	MCMP204 (N = 243)[b]	MCMP205 (N = 200)[c]	MCMP204 (N = 226)[b]	MCMP205 (N = 182)[c]
Enrollment	97	88	92	24
Participation	88	64	83	3

[a]Online homework system (OHS) involvement was categorized as either enrollment (created an account in the OHS) or participation (used the OHS to complete assignments). [b]Extra credit *offered* for OHS assignments in this course, a prepharmacy organic chemistry class. [c]Extra credit *not offered* for OHS assignments in this course, a prepharmacy organic chemistry class.

a nonzero score for the majority of the assignments, representing only 3% of the class overall. On the basis of the similarities in student demographics and class composition between Cohorts A and B, these data indicate that the extra-credit point incentive itself is critical to engaging students in the use of an OHS, regardless of their previous positive experiences with the same system.

■ DISCUSSION

Extra-Credit Point Incentives Can Boost Online Homework System Engagement and Promote Student Learning

High-performing undergraduate students in the biomedical sciences carry rigorous course loads and are pulled in many different directions. Those with a desire to go on to postgraduate training in research or professional school (e.g., medical or pharmacy training) know that maintaining high grades will be critical to acceptance in their chosen programs. When we compared the OHS use between two prepharmacy cohorts of second-year students in which both cohorts had experienced the functional benefits of OHS engagement during their first-semester organic chemistry course, we found that extra credit was a crucial incentive to motivate these students to enroll in the OHS and participate in the material. This is consistent with results reported by Richards-Babb,[1] in which students were significantly more likely to complete online homework that was worth a portion of their grade. As students learn to prioritize their time and balance their studies simultaneously between several challenging STEM courses, it is likely that they assign greater weight to activities that will directly result in some amount of point credit, whether or not they believe that the activity will benefit them indirectly as well.[13] It should be noted that the total amount of extra credit possible from using the system was minimal; the students were aware that the potential percentage contribution from their score on the OHS was only enough to provide a maximum ~0.28 point letter grade advantage in their total course grade. Despite this minimal direct benefit, that incentive appeared to be the key to inducing student participation in the OHS in our cohorts. Accordingly, our data seem to indicate that providing a small amount of extra credit for engagement and performance in an OHS can increase the likelihood that students will use, and therefore benefit from, the material.

Online Homework with Tutorial Feedback Provides "Personalized" Instructive Interaction

A key aspect of the online homework system used in this study was the incorporation of immediate, response-specific feedback and tutorial prompts, which we speculate (based on reports of other interactive systems)[14] were able to serve as a form of interactive mentoring on the material. Such tutorial and response systems have previously been shown to be effective and valued by students in chemistry classes.[5] Moreover, evidence from a study on use of online homework systems in introductory physics courses suggests the positive effects of online homework systems are augmented by implementation of an "interactive engagement" model in the classroom.[15] Our lecture style incorporates this type of model; therefore, it is possible that these factors synergized in our case study to bridge the gap between the needs of students and the economies of the large lecture-style class.

While we cannot rule out the contribution of overall work ethic to grade and its possible independent correlation with SWE, we analyzed survey responses for the students with SWE scores ≤2 to get a sense for how much outside of class time these students spent on the different study resources provided to them. We expected that students who spent a substantial amount of time on the textbook problems (either with or without an equivalent focus on the OHS assignments) would demonstrate stronger performance than those who focused only on the OHS; however, this was not the case. We observed only a very small increase in performance (which was not statistically significant) for students with SWE scores ≤2 who self-reported working mostly on the textbook problems offline (which would not provide response-specific feedback unless worked in the presence of an instructor or tutor) compared with students with SWE scores ≤2 who mostly focused on using the OHS as a study tool. The results from our case study—that OHS engagement was not superseded by independent, textbook-based problem solving—are consistent with a "surrogate mentoring" hypothesis,[14] and support the concept that online homework systems have the potential to be more than just rote practice and drill tools that emphasize "time on task" (as per Chickering and Gamson's recommendations[3]); in addition, they can also promote functional learning—even for a complex, abstract, and problem-solving-based subject such as organic chemistry—by encouraging active learning and giving prompt feedback.[1,3]

■ CONCLUSION

We set out to examine the effectiveness of an online homework system provided by Sapling Learning in our organic chemistry course for prepharmacy students. We had expected that textbook-based studying would have the strongest relationship with course outcomes. We found that student grades showed a significant benefit associated with engagement in the OHS, but surprisingly, no statistically significant incremental benefit was seen for students who self-reported spending substantial time on the textbook problems as well as the OHS. Students were generally positive about the system; however, we also found that extra credit (even when minimal with respect to its independent contribution to a student's potential grade in the course) provided an important point incentive to engagement in the OHS even for students who had previously experienced the benefits of the system and self-reported a desire to use it in the subsequent second semester of organic chemistry. These findings suggest that online homework systems might be effective for improving student learning, experiences, and success in large-enrollment organic chemistry courses, but that even for the most motivated students some degree of external incentive may be necessary to improve their likelihood of benefit.

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Notes

The authors declare the following competing financial interest(s): While the Sapling Learning online homework system is included in a promotion connected to Roberts Publishing for use with the textbook authored by GML, LLP and GML receive no financial enrichment as a result of this promotion and declare no financial conflict of interest with Sapling Learning or its online homework system used in this study.

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■ REFERENCES

(1) Richards-Babb, M.; Drelick, J.; Henry, Z.; Robertson-Honecker, J. Online Homework, Help or Hindrance? What Students Think and How They Perform. *J. Coll. Sci. Teach.* **2011**, *40*, 81−94.

(2) Crippen, K. J.; Crippen, K. J.; Earl, B. L. Considering the Efficacy of Web-Based Worked Examples in Introductory Chemistry. *J. Comput. Math. Sci. Teach.* **2004**, *23*, 151−167.

(3) Chickering, A.; Gamson, Z.; Poulsen, S. Seven Principles for Good Practice in Undergraduate Education. *Am. Assoc. Higher Educ. Bull.* **1987**, *17*, 140−141.

(4) Penn, J. H.; Nedeff, V. M.; Wiley, J. Organic Chemistry and the Internet: A Web-Based Approach to Homework and Testing Using the WE_LEARN System. *J. Chem. Educ.* **2000**, *7*, 227−231.

(5) Chamala, R. R.; Ciochina, R.; Grossman, R. B.; Finkel, R. A.; Kannan, S.; Ramachandran, P. EPOCH: An Organic Chemistry Homework Program That Offers Response-Specific Feedback to Students. *J. Chem. Educ.* **2006**, *83*, 164.

(6) Penn, J. H.; Al-Shammari, A. G. Teaching Reaction Mechanisms Using the Curved Arrow Neglect (CAN) Method. *J. Chem. Educ.* **2008**, *85*, 1291.

(7) Chen, J. H.; Baldi, P. Synthesis Explorer: A Chemical Reaction Tutorial System for Organic Synthesis Design and Mechanism Prediction. *J. Chem. Educ.* **2008**, *85*, 1699−1703.

(8) Sapling Learning Web page. http://www.saplinglearning.com/ (accessed Oct 2012).

(9) AAMC−HHMI Committee. *Scientific Foundations for Future Physicians*; Association of American Medical Colleges: Washington, DC, 2009. https://www.aamc.org/students/download/302644/data/hhmi.pdf (accessed Oct 2012).

(10) (a) Pursell, D. P. Predicted versus Actual Performance in Undergraduate Organic Chemistry and Implications for Student Advising. *J. Chem. Educ.* **2007**, *84* (9), 1448−1452. (b) Szu, E.; Nandagopal, K.; Shavelson, R. J.; Lopez, E. J.; Penn, J. H.; Scharberg, M.; Hill, G. W. Understanding Academic Performance in Organic Chemistry. *J. Chem. Educ.* **2011**, *88* (9), 1238−1242.

(11) (a) Bernold, L. E. Early Warning System To Identify Poor Time Management Habits. *Int. J. Eng. Educ.* **2007**, *23* (6), 1182−1191. (b) Hong, E. S.; Peng, Y.; Rowell, L. L. Homework Self-Regulation: Grade, Gender, and Achievement-Level Differences. *Learn. Individ. Differ.* **2009**, *19* (2), 269−276.

(12) Richards-Babb, M.; Jackson, J. K. Gendered Responses to Online Homework Use in General Chemistry. *Chem. Educ. Res. Pract.* **2011**, *12* (4), 409−419.

(13) Chiu, C. M.; Sun, S. Y.; Sun, P. C.; Ju, T. L. An Empirical Analysis of the Antecedents of Web-Based Learning Continuance. *Comput. Educ.* **2007**, *49* (4), 1224−1245.

(14) El-Mounayri, H.; Wasfy, T.; Fernandez, E.; Peters, J. Innovative Online Course Using an Integrated Virtual Reality Based E-Learning Tool with Course Management Tool. In *Innovative Techniques in Instruction Technology, E-learning, E-assessment and Education*; Iskander, M., Ed.; Springer: New York, 2008; pp 183−189. http://www.springerlink.com/content/w1862h901033m35n/ (accessed Oct 2012).

(15) Cheng, K. K.; Thacker, B. A.; Cardenas, R. L.; Crouch, C. Using an Online Homework System Enhances Students' Learning of Physics Concepts in an Introductory Physics Course. *Am. J. Phys.* **2004**, *72*, 1447.