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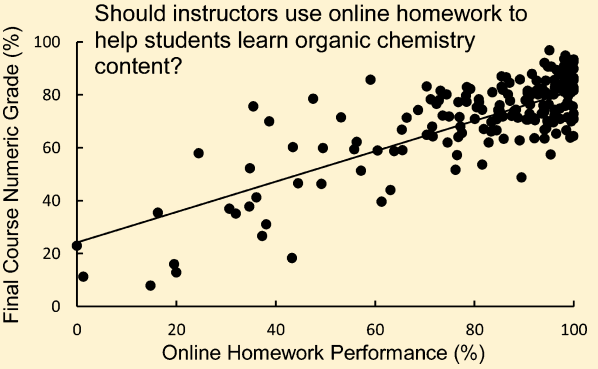
Student Perceptions of Online Homework Use for Formative Assessment of Learning in Organic Chemistry

Michelle Richards-Babb,*[,†] Reagan Curtis,[‡] Zornitsa Georgieva,[‡] and John H. Penn[†]

[†]C. Eugene Bennett Department of Chemistry and [‡]Department of Learning Sciences and Human Development, West Virginia University, Morgantown, West Virginia 26506, United States

ABSTRACT: Use of online homework as a formative assessment tool for organic chemistry coursework was examined. Student perceptions of online homework in terms of (i) its ranking relative to other course aspects, (ii) their learning of organic chemistry, and (iii) whether it improved their study habits and how students used it as a learning tool were investigated. Our students perceived the online homework as one of the more useful course aspects for learning organic chemistry content. We found a moderate and statistically significant correlation between online homework performance and final grade. Gender as a variable was ruled out since significant gender differences in overall attitude toward online homework use and course success rates were not found. Our students expressed relatively positive attitudes toward use of online homework with a majority indicating improved study habits (e.g., study in a more consistent manner). Our students used a variety of resources to remediate incorrect responses (e.g., class materials, general online materials, and help from others). However, 39% of our students admitted to guessing at times, instead of working to remediate incorrect responses. In large enrollment organic chemistry courses, online homework may act to bridge the student-instructor gap by providing students with a supportive mechanism for regulated learning of content.



KEYWORDS: *Second Year Undergraduate, Organic Chemistry, Internet/Web-Based Learning, Multimedia-Based Learning, Enrichment/Review Materials*

INTRODUCTION

Many undergraduates experience difficulties in learning organic chemistry. To a large extent, organic chemistry is a conceptual subject and not prone to rewarding students who rely solely on memorization or generated algorithms for learning. This assertion is supported by Raker and Towns who coded as conceptual a higher percentage of questions on organic chemistry exams than on general chemistry exams.[1] In fact, conceptual questions account for 90% or more of the test items that appear on the 2012 ACS standardized Organic Chemistry Exams.[2] Further, Ferguson and Bodner stress the need for "process-oriented" skills in organic chemistry relative to the "product-oriented" skills of general chemistry,[3] perhaps due to organic chemistry involving learning at the higher levels of Bloom's Taxonomy.[4] As such, students who more fully understand the underlying organic chemistry concepts,[5,6] steadily building up their conceptual knowledge base throughout the semester,[7] enabling them to apply, analyze, synthesize, and evaluate, are rewarded on organic chemistry course assessments. Moreover,

(i) an understanding of external representations (symbolic visualizations) used in chemistry,[8]
(ii) competence in communicating chemistry knowledge using external representations,[8]
(iii) an ability to formulate internal representations (mental models),[8]
(iv) the ability to interconvert readily from one representation to another (e.g., line structure to condensed structure, internal to external, two-dimensional to three-dimensional, verbal/linguistic to symbolic),[8−10]
(v) facility in representational processing (e.g., use of curved arrows to document mechanisms),[11,12] as well as,
(vi) facility in spatial reasoning skills[13] (e.g., mental rotations, three-dimensional visualization from two-dimensional representation)

also affect learning of organic chemistry. Representation use by practicing organic chemists is so important that representations appear in virtually every test item on present-day ACS standardized organic chemistry exams.[2]

In addition, students who display good study habits (e.g., study frequently, front-load their study, spend time arranging information, seek their instructor's help, complete practice problems/homework),[5] and use an array of spatial problem solving strategies (e.g., diagrammatic, analytic, and algorithmic)[14] tend toward more success in organic chemistry. Students who struggle with organic chemistry (as well as other STEM coursework) routinely underestimate the amount

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of time needed for exam preparation, overestimate their predicted performance on exams, and do not significantly change their exam preparation based on prior poor exam performance.[15]

Thus, organic chemistry instructors need to use pedagogies that support and bolster their students' learning of organic chemistry content. "The Seven Principles for Good Practice in Undergraduate Education" proposed by Chickering and Gamson[16] are a useful pedagogical framework for instructors of difficult subjects. The seven principles are

(1) encourage student-faculty contact,
(2) encourage cooperation among students,
(3) encourage active learning,
(4) give prompt feedback,
(5) emphasize time-on-task,
(6) communicate high expectations, and
(7) respect diverse talents and ways of learning.[16]

It has been argued that web-based practice and assessment systems (e.g., online homework) reinforce general chemistry instructors' utilization of this framework by directly addressing principles three, four, and five while indirectly addressing principles one and seven.[17,18] In fact, online homework use in general chemistry has been extensively studied by several research groups with quantitative findings ranging from significant improvements in final exam scores,[19,20] course success rates (%ABC grades),[21] pass rates (%A−D grades),[22] and retention.[17,22] Qualitative findings from these studies range from generally positive student attitudes toward online homework use[21] to students' perceptions of online homework as a useful course component.[22] One study also examined how students used the online homework as a learning tool to find solutions and to remediate incorrect responses (e.g., recheck work, consult online or in-person resources before a subsequent attempt).[21]

Use of online homework in organic chemistry has steadily increased since the year 2000 when Penn, Nedeff, and Gozdzik reported on its implementation and consequent "positive change" to the classroom environment.[23] Other researchers have extended the use of online homework for formative assessment of organic chemistry knowledge by

(i) integrating structure drawing and "tailored" student feedback into an organic chemistry online homework system,[24]
(ii) using online homework to deliver postclass questions to bridge out-of-class with in-class learning,[25]
(iii) assessing reaction mechanism knowledge by focusing on intermediates instead of curved arrows (Curved Arrow Neglect or CAN),[26] and
(iv) creating online randomized synthesis tutorials for improved understanding of organic reactions.[27]

Subsequently, many of these innovations have been folded into online homework systems developed by publishing companies and offered as companion supplements to their textbooks.[23,24,27]

Results and benefits of using online homework to assess organic chemistry learning include positive correlations between students' online homework or tutorial scores and corresponding exam scores[23,24,27,28] or grades,[18] improvements in students' drawing of mechanisms,[26] and providing the instructor with frequent feedback as to students' difficulties in understanding the material to support midcourse adjustments.[25] However, these benefits are only achieved if students actually use the online homework system. A recent study by Parker and Loudon highlighted the need to point-incentivize online homework use to achieve these benefits.[18] In addition, studies have found organic chemistry students to be generally positive about online homework use and not resistant to using it as a study aid.[18,23,24,28] However, the specifics of how organic chemistry students are using the online homework as a learning tool to find solutions and remediate incorrect responses have not been extensively studied. Our evaluation was devised to add to the knowledge base in this area and to address the following specific questions:

1. Do organic chemistry students perceive the online homework as useful to their learning in the lecture portion of the course? In particular, where does the online homework rank relative to other course aspects in terms of perceived usefulness? Do students perceive the online homework as helpful for (a) their learning of organic chemistry content and (b) improving their study habits?
2. How are organic chemistry students using the online homework as a learning tool? In other words, (a) how do students remediate an incorrect response and (b) what resources do students use to "learn from their mistakes"?

METHODS

Sample

A survey examining student attitudes toward online homework was administered during the last week of the semester to students attending two sections of organic chemistry I lecture. Students in both sections completed weekly online homework assignments, using the commercially available WileyPLUS system,[29] with their eventual online homework average counting 10% toward their final course numeric grade. Sixteen students withdrew from the course and 226 students completed the course with a grade. A total of 159 of 226 students completed the survey for a total response rate of 70%. The demographic makeup of survey completers was 104 (65%) females and 55 (35%) males. The majority of survey completers were sophomores (N = 84, 53%), while smaller proportions were juniors (N = 48, 30%), seniors (N = 18, 11%), freshmen (N = 4, 3%), and other (N = 4, 3%). One participant did not provide class information (1%).

To gauge if survey completers (N = 159) differed from those who did not complete the survey (noncompleters; N = 67), we compared the two groups on three indicators: final course numeric grade, average online homework score, and previous chemistry achievement (general chemistry II grade). Survey completers had higher final course numeric grades (M = 76.89, SD = 10.60, N = 159) than noncompleters (M = 69.99, SD = 17.55, N = 65). Two noncompleters received incompletes for the course and were therefore missing data for final course numeric grade. Completers also had higher average online homework scores (M = 92.00, SD = 13.59, N = 159) than noncompleters (M = 74.03, SD = 26.43, N = 67). Mann−Whitney U tests (accounting for non-normal grade and score distributions) indicate that these differences are significant for final course numeric grades (U = 4161.5, p = 0.022) and online homework scores (U = 2828.5, p < 0.001). However, these differences are not surprising given that noncompleters were absent from lecture at an average rate that was more than twice that of completers. Simply put, noncompleters were less likely to attend lecture on the day the survey was administered.

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Numeric equivalent letter grades (A = 4, B = 3, etc.) earned in prerequisite general chemistry II coursework were used to compare previous chemistry achievement of completers and noncompleters. Sample size varies slightly as 2 completers and 1 noncompleter were missing data for prerequisite coursework. The average previous chemistry achievement was slightly higher for completers (M = 2.57, SD = 0.83, N = 157) than noncompleters (M = 2.48, SD = 0.84, N = 66). These slight differences in previous chemistry achievement are not significant (U = 4980.00, p = 0.633).

Survey Instrument

We administered a survey described elsewhere to assess students' attitudes toward online homework as a study aid in organic chemistry.[21] The mean across 26 Likert-type items on that survey were analyzed and formed an overall attitude toward online homework scale (6 negatively worded items were reverse coded) with acceptable internal consistency (Cronbach α = 0.86).[30] The overall attitude toward online homework scale ranged from 1 to 5 where higher scores indicated more positive attitudes toward online homework.

An additional quantitative item asked students to rank 10 course aspects (e.g., online homework assignments, textbook, student solutions manual, review sessions, instructor-run lectures) from most useful (ranking = 1) to least useful (ranking = 10) in terms of supporting their perceived learning in the organic chemistry course. The percentage of students highly ranking (1, 2, or 3 rankings) each course aspect was obtained by summing the number of 1, 2, and 3 rankings and dividing by the total number of rankings received for each course aspect. Thus, a course aspect that was ranked by a total of 50 students and highly ranked (rankings of 1, 2, or 3) by 30 of the 50 students would have a percentage ranking of 60% (30 of 50) in terms of students' perceptions of the usefulness of that aspect for supporting their learning in the course. Four open-ended written free response items where students expanded on their online homework experiences also were analyzed.

Analyses

Descriptive statistics including frequencies, means, and standard deviations were calculated for individual Likert-type survey items, as well as the 26 item overall attitude toward online homework scale. The open-ended questions were subjected to thematic analysis. The coding system was developed following the process for content analysis laid out by Hsieh and Shannon.[31] Once the coding scheme was developed, two coders coded each statement individually with multiple codes applying to most statements. Inter-rater reliability was calculated on a statement level. Initial inter-rater reliability approached 80% across statements for complete agreement (requiring all codes applied to a statement to match exactly) and 95% for partial agreement (agreement on some codes, but not on others). Discrepancies were resolved through a consensual qualitative research approach, which emphasizes "consensus among judges to construct findings based on the use of words rather than numbers to reflect meaning in the data (p 197)."[32]

This research was reviewed and approved (Protocol No. 1405296859) by our Institutional Review Board (IRB) and was found to follow appropriate guidelines for research involving human subjects. Limitations inherent in the research discussed herein are that (i) better performing students were more likely to complete the survey due to the convenience nature of its administration, (ii) the use of open-ended questions may underestimate actual frequencies, (iii) the study was limited to a single institution, and (iv) potential differences between the two sections of organic chemistry did exist (e.g., different instructors, class meeting times and days, etc.).

Preliminary Analyses

Overall, students expressed relatively positive attitudes toward online homework use in organic chemistry. The average overall attitude toward online homework score for the sample was 3.85 (SD = 0.49) of 5 (5 = highest overall attitude toward online homework score), with individual scores ranging from 1.92 to 4.73. Further, any gender differences were also examined to rule out gender as a variable. The average overall attitude score for females was 3.87 (SD = 0.53, N = 104) and that for males was 3.81 (SD = 0.40, N = 55). On the basis of the Mann−Whitney U test, there are no significant gender differences for the overall attitude score (U = 2388, p = 0.087). Upon comparing final letter grades for the 226 students who completed the course, the 134 female students earned 104 of the ABC letter grades (success rate of 78%), whereas the 92 male students earned 67 of the ABC letter grades (success rate of 73%). There is no significant difference (z = 0.83, p > 0.20) between these success rates indicating similar organic chemistry course success rates for both female and male students. As a result, gender as a variable was ruled out and not included in further analyses.

RESULTS AND DISCUSSION

Perceived Utility and Course Performance

Partial correlations among online homework performance (average online homework score), final course numeric grade, and overall attitude toward online homework score were calculated controlling for previous achievement in general chemistry for the survey completers (Table 1). There are small

Table 1. Correlations among Online Homework Score, Final Course Numeric Grade, and Attitude Survey Score after Controlling for Previous Performance in General Chemistry Course

Variables Analyzed	1	2
1. Online homework score	-	
2. Final course numeric grade	0.426[a]	-
3. Attitude survey score	0.225[b]	0.242[b]

[a] p < 0.001. [b] p < 0.01.

and significant correlations between overall attitude score and online homework score (r = 0.225, p = 0.005) and between overall attitude score and final course numeric grade (r = 0.242, p = 0.002). We found a moderate and statistically significant correlation between online homework performance and final grade (r = 0.426, p < 0.001). These correlations are not surprising and are consistent with previous findings of positive correlations between online homework scores and exam scores[23,24,27,28] and grades.[18]

Course aspect rankings for both sections (Instructor A, Sec. 001 and Instructor B, Sec. 002) of the organic chemistry course are given in Table 2, for all course aspects, and in Table 3, for the top five ranked course aspects for each section. Despite slight differences in classroom pedagogy (i.e., traditional lectures delivered by both instructors, but different modes of in-class formative assessment), supporting resources (e.g., Instructor B provided optional, nongraded chapter problem sets), and testing strategies (e.g., Instructor A, computerized

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Table 2. Top Three Ranked Most Useful Course Aspects in Terms of Perceived Student Learning in the Lecture Portion of the Organic Chemistry I Course

Course Aspect	Number of Students Who Ranked Course Aspect as 1, 2, or 3 in Usefulness[a]		
	Sec. 001, Instructor A; N = 73 (Response, %)	Sec. 002, Instructor B; N = 63 (Response, %)	Totals N = 136 (Response, %)
Chapter problem sets and associated answer keys	Not offered	30 (47.6)	30 (47.6)[d]
WileyPLUS online homework mastery assignments[b]	66 (90.4)	24 (38.1)	90 (66.2)
WileyPLUS online homework chapter assignments (3 chances per question)	30 (41.1)	20 (31.7)	50 (36.8)
"Organic Chemistry" by Smith text	20 (27.4)	22 (34.9)	42 (30.9)
Student solutions manual to accompany text (if used)	10 (13.7)	12 (19.0)	22 (16.2)
Peer led team learning (if attended)	1 (1.4)	3 (4.8)	3 (2.2)
Exam review sessions (if attended)[c]	Not offered	9 (14.3)	9 (14.3)[d]
Back tests	30 (41.1)	16 (25.4)	46 (33.8)
Weekly instructor run lectures	45 (61.6)	48 (76.2)	93 (68.4)
Assigned uncollected text homework	5 (6.8)	5 (7.9)	10 (7.4)

[a]Ratings based on an end of course survey with a ranking scale: 1 = most useful; 2 = next most useful; to 10 = least useful. [b]Mastery assignments contained 10 questions with grading of 0%, 50%, and 100% for 0−5 correct, 6−9 correct, and 10 correct, respectively. Students had unlimited attempts to complete each mastery assignment until the due date. [c]An advanced undergraduate student voluntarily prepared and offered weekly exam review sessions to the organic chemistry I students in Section 002. [d]Percentages calculated from N = 63 since these course aspects were not offered to Section 001 students.

Table 3. Rank Ordering of Top Five Most Useful Course Aspects in Terms of Perceived Student Learning in the Lecture Portion of the Organic Chemistry I Course

Rank Ordering of Top Five Most Useful Course Aspects	Course Aspect	
	Sec. 001, Instructor A (Course Aspect, %)	Sec. 002; Instructor B (Course Aspect, %)
#1	WileyPLUS online homework mastery assignments (90.4)	Weekly instructor run lectures (76.2)
#2	Weekly instructor run lectures (61.6)	Chapter problem sets and associated answer keys (47.6)
#3	Back tests (41.1)[a]	WileyPLUS online homework mastery assignments (38.1)
#4	WileyPLUS online homework chapter assignments (3 chances per question) (41.1)[a]	"Organic Chemistry" by Smith text (34.9)
#5	"Organic Chemistry" by Smith text (27.4)	WileyPLUS online homework chapter assignments (3 chances per question) (31.7)

[a]Although both the back tests and the WileyPLUS online homework chapter assignments have the same percentage (41.1%), there were more ratings of 1 and 2 for the back tests, so it was rank ordered higher.

exams with questions similar to mastery online homework assignments; Instructor B, written exams with content aligned to online homework and problem sets), students in both sections ranked the weekly instructor run lectures (61.6% Instructor A, 76.2% Instructor B, and 68.6% overall) and the online homework mastery assignments[33] (90.4% Inst. A, 38.1% Inst. B, and 66.2% overall) as two of the more useful course aspects (see Table 3). The much higher ranking of the online homework mastery assignments by students in Instructor A's section (i.e., 90.4%, Instr. A versus 38.1%, Instr. B) may be attributable to Instructor A's computerized mode of testing, such that students appreciated most the study resource that most closely resembled their exams. Likewise, Instructor B's students gave high rankings to the chapter problem sets and associated answer keys (47.6% and #2 ranked in Table 3), even though this course aspect was optional and not graded. However, it is likely that Instructor B's students recognized the problem sets as more closely resembling their written exams and communicated their appreciation of this resource with high rankings. This finding is aligned with previous research in which general chemistry students ranked instructor run lectures and online homework as two of the more useful course aspects along with problem solving videos, an optional study resource that was closely aligned to their exams.[34]

The lower rankings of the text (30.9% overall) in terms of perceived usefulness are not surprising. In fact, prior research has shown that the amount of time organic chemistry students spend using the textbook is limited to about 3.3 h per week.[35] Further, for the 26% of students in Parker and Loudon's study who self-reported spending more time studying and working problems in the text than completing online homework problems, additional time spent studying the text was not correlated to improved course performance beyond that afforded by completing online homework.[18] They speculate that the immediate feedback offered by online homework more effectively supports student learning than time spent studying the text. Likewise, we found that the text received lower perceived usefulness rankings (30.9% overall) than the online homework (66.2% overall). These lower rankings are perhaps not surprising given that students would not associate the text as garnering immediate points toward their final letter grade.

The lower rankings of the exam review sessions (14.3% overall) are also expected. Optional exam review sessions have been found to have attendance that (i) is low and (ii) does not correlate to improved grades.[36] We found similar results for our students in that average attendance at weekly review sessions (i) was 20.2% (N = 91) overall, but (ii) improved to 35.2% just prior to the first two exams and 57.1% prior to the third exam. In addition, review sessions were not well-attended by D and F letter grade students (i.e., students who should best benefit from attending). Thus, it is not surprising that our students rated the weekly review sessions less useful to their learning.

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Two Likert-survey items also provided information on students' perceptions relevant to online homework utility for learning organic chemistry content. The mean and standard deviations for students who responded to these two items are presented in Table 4. The average scores for these items indicate that students utilized the online homework assignments and suggest perceived utility by students.

Table 4. Mean and Standard Deviation for Survey Items Addressing Students' Perceptions Relevant to Online Homework Utility for Learning Organic Chemistry Content

Survey Item	Mean (N = 158)[a]	SD
I looked over the graded online homeworks in order to learn from my mistakes.	4.39	0.87
The online homework assignments did not further my understanding of organic chemistry concepts.	1.83	1.07

[a]Likert survey scale: 1 = strongly disagree, 2 = disagree, 3 = neutral (neither agree or disagree), 4 = agree, and 5 = strongly agree.

Further, one open-ended question inquired about any changes in student learning habits (*Has use of the online homework changed your chemistry study habits? If so, in what way? Do you study chemistry more or less? Do you spread out your chemistry study over more days or just study chemistry on the days that the online homework is due?*). The content analysis of student responses revealed ways that students utilized the online homework in their course preparation. Survey completers provided 150 responses to this question and indicated that (i) they used online homework as a practice tool (12%); (ii) they used online homework as immediate knowledge assessment to identify what they needed to study (5%); (iii) online homework helped them understand course content, retain information, and master the material (10%). While these rates are relatively small, we acknowledge that the question did not specifically address the particular ways in which students utilized the homework assignments so responses directly to that point likely were highly salient for those students.

Changes in student study habits were examined through two Likert-type survey items and the open-ended question given in the preceding paragraph. The mean and standard deviations for students who responded to these two items are presented in Table 5. Student responses indicate strong agreement that the online homework assignments promoted more consistent study habits (M = 4.23, SD = 1.00). Scores relative to the online homework assignments reducing "cramming" before exams were less positive, but still above the midpoint (M = 3.43, SD = 1.43).

Table 5. Mean and Standard Deviation for Survey Items Addressing Changes in Student Study Habits as a Result of Online Homework

Survey Item	N	Mean[a]	SD
The weekly deadlines for online homework assignments were helpful by encouraging me to study in a more consistent manner.	159	4.26	0.98
I spent less time cramming for chemistry exams this semester than for previous chemistry courses.	158	3.46	1.43

[a]Likert survey scale: 1 = strongly disagree, 2 = disagree, 3 = neutral (neither agree or disagree), 4 = agree, and 5 = strongly agree.

A total of 150 students provided answers to the open-ended question on whether use of online homework had changed their study habits. The content analysis revealed that a majority of students indicated changes in their study habits including studying more or more often (55%) or not cramming for exams (9%). About 14% of respondents admitted that the homework assignments were overall beneficial for their study habits and 4% shared that the homework assignments helped them with keeping up with course material. Nevertheless, a number of students admitted that the online homework did not have an impact on their study habits (12%).

Utility as a Learning Tool

One open-ended question inquired about the type of resources the students used to remediate an incorrect response (*After incorrectly answering an online homework question on your first attempt, what did you do? Did you guess at the answer for the remaining attempts or did you seek help from the link or text?*). A total of 158 students provided a response to this question. Student responses revealed that students utilized a number of different resources. These resources included materials from class (e.g., class notes), assigned course materials (e.g., text), resources available within the online homework system (e.g., hints, links, online books, go tutorials), online general materials (e.g., Internet, google), and help from others (e.g., a teaching assistant, tutor, a friend, a study group). The frequencies and proportions of each category as a fraction of the number of responses provided are displayed in Table 6. About 28% of the respondents indicated that after getting a question wrong, they would rework or retry the problem. A number of students indicated that they did not use any outside resources but rather looked at the wrong answer, memorized the answer, reset the assignment, or guessed again to get to the correct response (39%). This type of behavior was more common for students who completed mastery online homework assignments[33] perhaps because problem types within the mastery assignments were more likely to be formatted as multiple choice.

Table 6. Frequencies and Percentages for Each Response Category

Category	Total (Response, %)[a] (N = 158)
Materials from class	46 (29)
Assigned course materials	41 (26)
Resources available within the online homework	28 (18)
Online general materials	5 (3)
Help from others	7 (4)

[a]Responses may fall in more than one category.

CONCLUSIONS

We believe that use of online homework has improved our students' organic chemistry learning by improving their study habits and attitudes toward the course and its instructors. Similar to Parker and Loudon's research,[18] we found a moderate and statistically significant correlation between online homework performance and final grade. In addition, our students expressed relatively positive attitudes toward use of online homework (average survey score = 3.85 of 5) with a majority indicating improved study habits (studying more or more often and less cramming) with its use. Improved study habits are important since research indicates that "study

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behaviors can overshadow prior grades" (p 1241) in organic chemistry coursework.[5] We found no significant gender differences in students' attitudes toward use of online homework or in their success rates (%ABC letter grades) in the organic chemistry course. Richards-Babb and Jackson, in their research on online homework use in general chemistry coursework, also found no significant gender differences in students' success rates with its use, but did find a significant female to male success rate gap without its use.[17] Overall, our students perceived the online homework mastery assignments as one of the more useful course aspects for learning organic chemistry content. We also observed that students ranked course components that more closely resembled their exams as more useful toward their learning than other course components. Our students used a variety of resources to remediate incorrect responses ranging from class materials and resources available within the online homework system to general online materials and help from others. Unfortunately, 39% of our students admitted to guessing at times instead of reworking or remediating an incorrect response. This is a significantly higher percentage ($z = 1.73$, $p < 0.05$) than the 30% of guessing (as a last resort and immediately) reported of general chemistry students when completing online homework.[21] However, the numeric nature of general chemistry content allows for creation and use of more algorithmic problem types, for which memorizing the answer from previous attempts or guessing does not ensure success. The non-numeric and conceptual nature of organic chemistry and a reliance on representations to express knowledge and the focus on "process-oriented skills" do not readily allow for problem types other than multiple choice. However, this trend is changing as online homework systems become more advanced with the ability to recognize and properly grade chemical representations[26,37] and mechanistic products.[27]

Similar to the students in Parker and Loudon's study,[18] where only 26% of students self-reported spending more time studying and working problems in the text than completing problems within the online homework system, we found that the text received lower perceived usefulness rankings (31% overall) than the online homework (66.2% overall). These lower rankings are perhaps not surprising given that students would not associate the text as garnering immediate points toward their final letter grade. In addition, Parker and Loudon found that additional time spent studying the text and working through problems did not correlate to improved course performance beyond that afforded by completing online homework.[18] In fact, Malik et al. found that organic chemistry students who completed online homework outperformed students who completed written homework on an end of semester ACS exam.[28] They and others[18,21] speculate that the immediate feedback offered by online homework more effectively supports student learning than time spent studying the text or time spent completing written homework. Other researchers[17] have argued that online homework bolsters students' learning by directly addressing three of Chickering and Gamson's "Seven Principles for Good Practice in Undergraduate Education", specifically "encouraging active learning", "giving prompt feedback", and "emphasizing time-on-task", and indirectly addressing others, specifically "encouraging student-faculty feedback" and "respecting diverse talents and ways of learning".[16] We tend to agree with this assessment since online homework (i) forces students to engage with the material and actively apply their knowledge to solving novel problems, (ii) immediately grades question attempts and provides feedback on question correctness, at a minimum, and (iii) encourages students to put in more hours studying in a regulated manner to meet weekly online homework deadlines concurrent with its completion. This regulation is important as research indicates that more frequent study and completion of practice problems are both correlated to higher course grades, especially at the beginning of a course.[5] In addition, previous research supports the notion that, in difficult courses, there is a positive correlation between the student-instructor relationship and the students' confidence as well as predicted grade.[38] In large enrollment courses, online homework may act to bridge the gap between the students and the instructor by providing students with a supportive mechanism for regulated learning of content.

Organic chemistry instructors can use our findings to discuss with students the benefits (e.g., improved study habits including more frequent study, decreased tendency to cram for exams, and final grades positively impacted by performance on online homework assignments) of completing online homework assignments. However, when choosing an online homework system for organic chemistry, instructors should take into account the potential superiority of systems that minimize the quantity of multiple choice questions, while maximizing the quantity of algorithmic, nonmultiple choice question types, involving drawing and grading of structures and mechanisms.[24,26,27,37] To extend this research, future work should examine the impacts of reducing the use of multiple choice question types and how this affects students' use of online homework as a learning tool (e.g., their abilities to remediate an incorrect response and what resources they use to learn from mistakes). In addition, a study aimed at gendered differences in use of online homework in organic chemistry coursework, and whether our finding of no significant difference in success rates between female and male students can be attributed to use of online homework or to some other factor, would be of interest to the field.

AUTHOR INFORMATION

Corresponding Author

*E-mail: Michelle.Richards-Babb@mail.wvu.edu.

Notes

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