Lessons from Chemists on Improving Learning Behaviors and Outcomes

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Abstract
The hybrid General and Organic Chemistry courses have been designed to promote the development of students' cognitive ability and confidence in utilizing chemical concepts. The approaches used could have utility in other courses focused on integrating skill development with critical thinking and reasoning. Data has been collected from more than 150 students over 3 years. The courses highlight:
- An integrated peer learning structures with mediated learning strategies that ventured beyond the classroom through question & answer blogs and online office hours.
- Rubrics and grading checklists used to evaluate students’ competencies and approaches to problem solving.
- Assessment of students' perceived value of course activities to their mastery of content.
- Analysis of student learning outcomes in courses using flipped methods to those utilizing traditional methods for content delivery.

Presented here is an overview of the technology enabled approach. The presentation highlights the learning outcomes, perceptions, and motivation of two cohorts that were maintained throughout General Chemistry I & 2 and Organic Chemistry I: those beginning the General Chemistry course sequence in Fall 2012 (cohort 1) and Fall 2013 (cohort 2).

Format of Flipped Courses
The flipped General and Organic Chemistry courses utilized complimentary pedagogy (shown below) that is largely technology driven.

Students: The same population of students matriculated through both the General Chemistry two semester sequence and the first semester of Organic Chemistry with the exception of those lost due to attrition. The students were primarily chemistry and biochemistry majors.

Course Size: Course size in General Chemistry were capped at 40 and at 30 for Organic Chemistry.

Outcomes for General Chemistry

Average ACS Final Exam Raw Scores – 4 Academic Years

Students’ mastery of concepts was measured using standardized American Chemical Society (ACS) exams as course final exams. The General Chemistry I (Fall term, F) courses used the 2002 first term General Chemistry exam and the General Chemistry II courses (spring term, S) used the 2003 comprehensive General Chemistry exam. It was found that final exam scores improved upon implementation of the blended courses as compared to the traditional lecture courses. The graph below shows average test scores out of a possible 70 correct responses.

- National averages are 41.73 and 41.03 for the fall and spring exams, respectively.
- Hibbard taught all courses indicated as Sec 3.
- The blended format was used during 2012-13 (cohort 1) and 2013-14 (cohort 2).

ANOVA: Average ACS Final Exam Raw Scores – 4 Academic Years
ANOVA statistical analysis was performed on the ACS standardized final exam scores for General Chemistry I & II courses taught by Hibbard for the past four years.
- Courses taught using the blended method during Spring 2013 (cohort 1) and Spring 2014 (cohort 2) were compared to those courses taught using traditional methods (Spring 2010 and Spring 2011).
- The analysis showed that there were significant differences in test scores between those courses taught by Hibbard using blended instructional methods as compared to the blended approach (p < 0.05; 95% confidence interval).

Class (F – J)

Mean Difference (I-J)

S10 – S11

0.348

0.474

0.408

0.756

0.067

S10 – S13

0.141

0.170

0.158

0.167

0.154

0.181

S11 – S13

0.071

0.031*

0.052

0.000*

0.983

Significance (p)

0.000*

Student Perception of Resources: General Chemistry

In order to measure student perception: regarding the blended course strategies used in the courses, a 50-question survey was developed and administered to First Years (FY), Sophomore (So) and Juniors (Jr) who had enrolled in the majors sections. Survey results showed that students believed online narrated lectures (avg=4.5) and POGIL strategies (avg=4.0) met their learning needs. While the majority of students agreed that the gated testing system to be challenging, most agreed that the system prepared them for the final exam (avg=3.8). An essential aspect of the blended course is to make students responsible for their own learning and for them to relate the level of preparation to success in the course. This is evidenced by their response to the learning motivation question regarding learning responsibility and perceived success (avg=4.2).

- Survey questions were categorized based on the topics given in the table below.
- Five questions were selected for each category and analyzed for each classification of respondent.
- Likert Scale: 1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly Agree (standard deviation).

<table>
<thead>
<tr>
<th>Category</th>
<th>FY</th>
<th>SO</th>
<th>JR</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTENT DELIVERY</td>
<td>4.0 (0.2)</td>
<td>4.3 (0.2)</td>
<td>4.3 (0.0)</td>
</tr>
<tr>
<td>CLASSROOM SESSIONS</td>
<td>4.0 (0.3)</td>
<td>3.7 (0.4)</td>
<td>4.0 (0.6)</td>
</tr>
<tr>
<td>ASSESSMENTS</td>
<td>3.9 (0.7)</td>
<td>3.6 (0.1)</td>
<td>3.8 (0.5)</td>
</tr>
<tr>
<td>LEARNING MOTIVATION/ PRIOR EXPERIENCE</td>
<td>3.8 (0.3)</td>
<td>3.6 (0.27)</td>
<td>3.7 (0.81)</td>
</tr>
</tbody>
</table>

Student Perceived Value of Resources: Organic Chemistry

The data represents the resources student utilized the most to master concepts associated with each exam n = 26. The results were heavy reliance on in-class practice and proctor’s notes for all exams. Further quantitative analysis is needed to correlated student performance to their use and perception of learning resources.

Outcomes for Organic Chemistry

Prior Knowledge Assessment

Students were assessed to determine their knowledge of fundamental Organic Chemistry concepts at the beginning of the course.
- The assessment contained 25 questions spanning 3 categories given below.
- Students assessed were from courses using blended strategies and those using traditional strategies.
- Cohort 1 (Blended 2013) and cohort 2 (Blended 2014).
- The score represents the average number of correct responses per number of questions in each category (standard deviation).

<table>
<thead>
<tr>
<th>Concept Category</th>
<th>Blended 2013</th>
<th>Traditional 2013</th>
<th>Blended 2014</th>
<th>Traditional 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawing/Interpreting Organic Structures</td>
<td>0.37 (0.02)</td>
<td>0.30 (0.02)</td>
<td>0.45 (0.19)</td>
<td>0.42 (0.02)</td>
</tr>
<tr>
<td>Naming Organic Structures</td>
<td>0.34 (0.01)</td>
<td>0.34 (0.01)</td>
<td>0.29 (0.11)</td>
<td>0.45 (0.47)</td>
</tr>
<tr>
<td>Structure/Property Relationship of Organic Molecules</td>
<td>0.31 (0.05)</td>
<td>0.32 (0.06)</td>
<td>0.41 (0.18)</td>
<td>0.35 (0.12)</td>
</tr>
</tbody>
</table>

Concept Mastery

Student mastery of course content was measured using the standardized final exam, 2010 first term Organic Chemistry exam from the American Chemical Society. Values represent the number of correct responses out of 58 questions (standard deviation):
- National Average = 32.64 questions (97.3)
- Average across all sections = 27.08 questions (10.79)
- Average for sections using blended learning = 29.75 questions (11.70)

In 2014, there appears to be a significant improvement in learning outcomes in comparison to those in 2013. The most notable gain in knowledge relates to naming organic structures for 2014 (based on pre and post knowledge). Below is a summary of student performance by concept.
- The score represents the average number of correct responses per number of questions in each category (standard deviation).

Student Self-reported Motivation for Science

Survey Adapted from Gius, S., Science Motivation Questionnaire II
The data represents the self-assessed frequency at which students demonstrated various types of motivation (given below). The pre and post results suggest that students sustained similar levels of motivation throughout the course. However, a modest improvement was observed for self-determination. Scale: 0 = Never, 1 = Rarely, 2 = Sometimes, 3 = Often, 4 = Always. Cohort 1 = Blended 2013, cohort 2 = Blended 2014 (standard deviation).

Lessons

- Students do not prefer using their own device due to ease of distraction, preference for pen & paper, and limited personal data plans. However:
  - If required to use their own device, students would prefer cellphones instead of laptops or tablets due to portability.
  - Students believe that technology enhanced their learning experience.
- A cultural shift is needed for students to become acclimated to the required out-of-class activities and to overcome the stigma of “teaching one’s self”. However:
  - The effort exerted by students in the flipped course allows the student to demonstrate more responsibility and self-determination in their success.
  - There appears to be an enhanced student performance in the flipped courses in comparison to those in the traditional courses.
- There can be a learning curve when identifying appropriate technology and the effective use of technology in courses.
- A significant amount of time is required to develop learning resources.
- It may be difficult to resist the urge to lecture.

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