Purdue University

NOMINATION FORM FOR

HELPING STUDENTS LEARN AWARD

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___Reorganization of Organic Chemistry Curriculum to Improve Student Learning___________

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Nominations must be sent electronically to cie@purdue.edu. Nominations must be received no later than 5 pm, Monday, January 31, 2022.

Reformation of the Organic Chemistry Curriculum to Promote Student Learning

Organic Chemistry is typically taught at the undergraduate level as a full-year sequence. At Purdue, this is reflected in the CHM 25500/25600, 26100/26200 and 26505/26605 sequences that encompass over 1200 students per year. A widely recognized problem with the standard undergraduate Organic Chemistry curriculum is that of declining student test scores during the second semester.[1] This problem has been ascribed to the quantity of information presented in the middle of the second semester and students' reliance on rote memorization as a strategy to master the quantity of information presented.[2,3] The students' reliance on rote memorization has, in turn, been attributed to the students' lack of an organizing principle to the material being presented.[3]

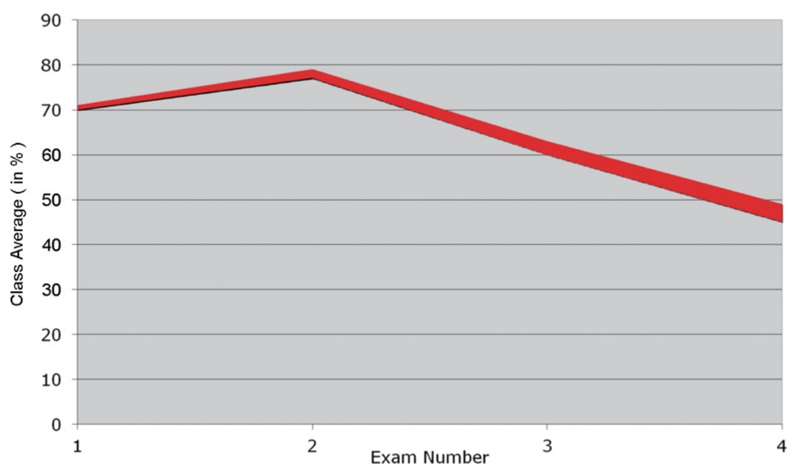

Figure 1. The observed decline in second-semester test scores in a typical organic chemistry class (From Ref. 1).

One problem facing students and instructors alike is that the presentation of Organic Chemistry in textbooks has remained largely unchanged since the publication of Morrison and Boyd's seminal textbook in 1959.[4] A comparison of modern textbooks to that of Morrison and Boyd reveals very few changes to the organization of the material presented despite a revolution in our understanding of organic chemistry pedagogy during the intervening years. This is particularly problematic because the organizational method used in virtually all undergraduate Organic Chemistry textbooks – the functional

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[1] Handy, S. S. in *Adv. Teach. Org. Chem.*, Ch. 7, pp. 115-121, ACS Symposium Series (2012).
[2] Duffy, A. M., Doctoral Dissertation (unpublished), University of California, San Diego, 2006.
[3] Bhattacharyya, G.; Bodner, G. M. *J. Chem. Educ.* **2005**, *82*, 1402-1407.
[4] Morrison, R. T. and Boyd, R. M. *Organic Chemistry,* Prentice Hall, 1959.

group approach – results in a fragmentation of many of the central concepts, resulting in a perceived lack of coherence.[5]

To combat this lack of cohesion in the curriculum and in turn to reduce the decline in second-semester test scores, Professor Mark Lipton instituted a highly successful, complete transformation of the curriculum in the chemistry majors' organic chemistry class (CHM 26505 and CHM 26605) in 2013. The objective of this transformation was to present the material using a modern "mechanistic" organization that unites related reactions in such a way as to assist student's assimilation of the material. Concurrently, Professor Lipton also instituted several important semantic reforms to simplify the language used and promote connections to earlier topics learned. Because no textbook existed that followed this structure, Professor Lipton created an online "Libretext" using the Libretext platform created at UC Davis.[6] This Libretext has the same organizational structure as the class and is free to use, thereby lowering costs to the students.

The novel approach employed by Professor Lipton emphasizes reasoning from core concepts, a strategy suggested by the "assimilation theory" of Ausubel and Novak.[7] In this theory, the ability of a student to assimilate new knowledge is entirely dependent on what the student has already learned. Such a process is viewed as "anchoring" new knowledge to previously learned concepts. To do this with organic reaction mechanisms, Professor Lipton identified what he considered to be the "core concepts" of organic chemistry and presented them early in the first semester of his class. Importantly, this enabled him to introduce organic reactions with reference to previous learned concepts about acidity and basicity, electronegativity and valence electron configuration.

Similarly, Professor Lipton's semantic reforms were intended to both simplify the distinctions between various types of reactions and to draw parallels between reaction classifications and previously learned concepts such as acidity and basicity. These semantic reforms were a sharp departure from the orthodoxy of organic chemistry pedagogy and are unique to Professor Lipton's curriculum.

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[5] Graulich, N.; Bhattacharyya, G. *Chem. Educ. Res. Pract.* **2017**, *18*, 774-784
[6] The LibreTexts for the revised curriculum can be found at https://chem.libretexts.org/Courses/Purdue/Purdue%3A_Chem_26505%3A_Organic_Chemistry_I_(Lipton) and https://chem.libretexts.org/Courses/Purdue/Purdue%3A_Chem_26605%3A_Organic_Chemistry_II_(Lipton)
[7] See Grove, N. P.; Bretz, S. L. *Chem. Educ. Res. Pract.* **2012**, *13*, 201-208 and references therein

Assessment of the Curricular Reforms

To assess the impact of the changes made to the organic curriculum, several metrics of student performance were compared between the five years preceding the curricular changes with the four years since the changes were implemented. Professor Lipton taught both versions of the class and employed the same grading scheme (vide infra). One important metric is the previously noted decline in test scores during the second semester of an introductory organic chemistry sequence.[1] As shown in Figure 2, such a decline can be seen in the mean test scores from the five pre-change years (752 students). After reaching a high of 75 on Exam 2, the scores declined through Exam 3 to the comprehensive Final Exam. This can be notably contrasted with the average scores obtained in the four years after the curricular change (317 students), as seen in Figure 2. Although the scores of Exam 1 and Exam 2 were effectively identical with those obtained prior to the change, the Exam 3 score was higher than either of the previous two and the Final score, although lower, still stood 7 percentage points higher than those from before the change, reflecting greater student comprehension of the material. Although the material tested on in the three midterms of the revised curriculum differs markedly from that in the midterms of the traditional curriculum, it should be noted that the comprehensive Final exams of both traditional and revised curriculum cover the same material and are identical in format.

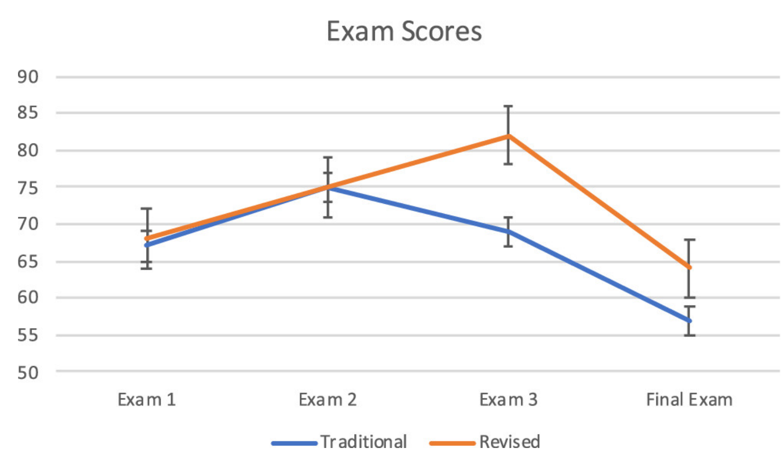

Figure 2. Mean exam scores (reported as a percentage) for traditional (blue) and revised (orange) curricula. Error bars represent the standard deviation of the mean exam scores.

Another significant metric that can be examined are the final grades obtained in the two versions of the course. Shown in Table 1 are the grade distributions and class averages from before and after the change was implemented, each representing a 4-year mean. Grades in both versions were assigned on a strict percentage basis: 90% for an A, 80% for a B, etc. The change in curriculum has resulted in a sharp increase in the number of A and B grades awarded and a resulting decrease in the number of C, D and F grades given. It is essential to note that these changes did not result from an adjustment of the grade cutoffs, which remain virtually unchanged. The same notable changes are seen in the class average, which increases by an average of 7 percentage points as a result of the curricular changes.

Table 2. Grade Distributions and Class Averages for Both Traditional and Revised Curricula

Final Grades	Students Receiving a Letter Grade, Mean % ± SD, by Curriculum Type	
	Traditional[a]	Revised[b]
A	24 ± 3	36 ± 7
B	24 ± 5	31 ± 2
C	28 ± 5	23 ± 3
D	18 ± 4	6 ± 2
F	7 ± 3	5 ± 0.5
Average	76 ± 2	83 ± 3

[a]Data reported for the traditional curricular approach represent 5 years and 752 students.
[b]Data reported for the revised curricular approach represent 4 years and 317 students.

The effects of the implemented curricular changes were also explored through the use of a Qualtrics survey. In particular, when students in the revised curriculum were asked about whether they "felt that they better understanding of organic reactions than their friends in other organic chemistry classes" and whether they "relied on rote memorization to learn the material" they responded 2.1±0.4 (1 = strongly agree, 5 = strongly disagree) to the first question and 4.2±0.3 to the second over the four years polled. Professor Lipton has since published his findings about his curricular changes in the *Journal of Chemical Education*, the premier academic journal for research in education.[8]

[8] Lipton, M. A. *J. Chem. Educ.* **2020**, *97*, 960–964.

Professor Lipton's transformation of the chemistry majors' Organic Chemistry course has had a profound impact on the 512 students he has worked with since its inception. He is currently working with Purdue's chemistry faculty to implement his groundbreaking approach to the other Organic Chemistry courses for the over 1000 life science and engineering students we teach each year. Professor Lipton has been invited to discuss his curricular reforms at University of California, Davis and Marquette University. Moreover, Professor Lipton's approach has been adopted recently at Marshall University and is currently being evaluated for adoption by several other chemistry departments.