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Dynamic Discussion and Informed Improvements: Student-led Revision of First-Semester Organic Chemistry

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DYNAMIC DISCUSSION AND INFORMED IMPROVEMENTS: STUDENT-LED REVISION OF FIRST-SEMESTER ORGANIC CHEMISTRY

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The Idea *(Lou)*

I came up for air in December of 2013 after finishing my first semester as an assistant professor of chemistry at Haverford College. After carefully stacking 78 graded organic chemistry final exams on the top shelf of my office, I sat down to reflect on what had been a whirlwind experience. While I had participated in the Teaching and Learning Institute at Bryn Mawr and Haverford Colleges, and worked closely with a student consultant throughout the semester, this was the first time I was relaxed enough to ask myself some fundamental questions: *Did the overall structure of the course make sense? Did my forms of assessment align with my course objectives? What could I do to improve this class for future students?*

Indeed, I was already thinking ahead to the Fall 2014, when I would be teaching this class for the second time. I wanted to make informed improvements to the course while the material was fresh in my mind. I had gathered some useful information from the end-of-semester evaluations, but what I really craved was a dynamic discussion with my former students. After all, they were the ones who sat through each lecture and worked through each assignment. They held the insights that I needed to make mindful revisions to the course materials and pedagogical approaches.

In this essay, my students and I share our experience of creating and executing a student-led revision of first-semester organic chemistry. While I wrote the section focused on the revision process and the outcomes for the course, the section on the outcomes for student consultants and the conclusion were a collaborative effort between the student consultants and myself.

The Student-led Revision Process and Its Outcomes for the Course *(Lou)*

As I began to think about how to create the dynamic discussion with my former students, I was thrilled to learn that the Teaching and Learning Institute and the Haverford College Provost's Office would support hiring a small team of former students to facilitate course revision. I was also pleasantly surprised that of the 78 students in my course, 22 were interested in participating in this student-led course revision process. Upon reviewing their application materials over winter break, I offered three students the opportunity to work with me as paid consultants over the course of the spring semester. While these students all performed well in the course, they have distinct personalities and perspectives on the class.

During our first meeting, we identified seven different themes and decided to dedicate two weeks to each theme. We scheduled weekly meetings on Thursday mornings to discuss our progress and any challenges encountered by the student consultants. We identified "needs" within each theme and brainstormed "actions" to meet these needs. The themes, needs, and action items that we covered over the course of the semester are outlined below along with some reflections on each. Taken together, these illustrate the ways in which the student consultants' insights shaped my rethinking of multiple aspects of the course.

We identified key needs as a group by examining the course objectives and assessment strategies outlined in the syllabus. The course objectives included students being able to do the following by the end of the semester:

1. Recognize, name, and draw the structure of all general classes of organic compounds found in biological systems.
2. Predict the reactivity of a molecule in a biological system based on its chemical structure.
3. Understand the fundamental organic reactions that underpin life.
4. Determine reactions that can be carried out to accomplish a specific biological transformation.
5. Predict the mechanism of organic biological reactions.
6. Draw parallels between how synthetic chemists make molecules versus how nature makes molecules.
7. Locate, read, and understand primary journal articles and scientific review articles.
8. Present the biosynthetic pathway of a natural product.

Assessment strategies included three midterm exams throughout the semester, one final exam, a final presentation on a topic related to the organic chemistry of biomolecules, pre-lecture quizzes, and weekly problem sets.

We asked ourselves: *Did these different tasks fulfill the objectives of the course and help students learn the material? What could be improved upon? What would be helpful for future students?*

Week 1: General organization

Need: Incorporate feedback from last semester.

Action: Reviewed end-of-semester evaluations and pull out constructive feedback. Discussed general design of course and brainstormed ways for improvement. Areas identified for improvement included: General timing of major assignments (exams and poster presentations), balance between assigning practice problems versus exercises designed to think about key concepts, and the role of the "Chemistry Question Center" in enabling student learning.

Week 2: Poster Presentations

Need: Students enjoyed the poster presentations and symposium, but these events fell at a difficult time in the semester. The presentations ultimately felt a bit rushed and hectic.

Discussion: We first discussed whether we wanted to keep the poster project or replace it with another type of capstone project. While the poster symposium requires additional time spent out of class, many students enjoyed presenting on a topic and found the experience to be valuable. Once we confirmed that we wished to keep the poster project, we determined that our goal should be to provide more resources for students and find the ideal time within the semester to have a symposium.

Action*:* Changed the final due date of the poster presentation capstone project and provided scaffolding by introducing several milestones with deadlines earlier in the semester. Created a binder of previous year's posters to serve as reference for students the following year.

Week 3: Pre-lecture quizzes

Need**:** Questions created for pre-lecture quizzes last semester are archived, but not organized by topic. The questions must be mapped by topic if they are to be efficiently used for review or in subsequent years.

Discussion: Our discussion around this need focused primarily on how to categorize these questions. Most questions can be put into multiple topics and can be asked throughout the semester. For example, a spectroscopy question can also be related to nomenclature. We decided to assign questions like these to multiple categories. While we initially thought one consultant could tackle this need, the amount of questions led us to divide the task so each student consultant was responsible for one-third of the question bank.

Action**:** Binned Pre-lecture quizzes by topic/subtopic.

Week 4: Problem sets

Need: Engage students in answering questions at the interface of chemistry and biology that do not simply have a "right" and "wrong" answer.

Action: Created a set of qualitative open-ended "key concept" questions that can be included in the weekly problem set assignments. The "key concept" question writing was a collaborative effort that took place during one of our weekly meetings.

Need: Some students became dependent on the Chemistry Question Center (CQC), tutors, or peers and therefore struggled on exams when these resources were not available to them.

Discussion: The student consultants shared their experiences and reflected on their own use of the CQC. We recognized that most students came to the question center the night before the problem sets were due and these students would lean on the teaching assistant (TA) and others walk them through problems. While for some CQC was an invaluable resource for processing

and learning material, it seemed that other individuals used CQC as a crutch. Therefore, we turned our attention to restructuring the collaboration between the students and the TA. We discussed other models of collaborations from our other courses at Haverford, especially those successfully executed by the Mathematics Department.

Action: Revised guidelines for completing problem sets such that students can collaborate with their peers and TAs, but that the student must complete the final version alone.

Week 5: Exams

Need: Some questions were unclear and/or were not very effective in helping students achieve their learning goals.

Discussion: We began discussing this need by examining the roles of problem set questions, recitation questions, and exam questions. We agreed that it is better for students to be over-prepared rather than under-prepared for an exam and that the problem set questions should be as challenging (if not more challenging) than exam questions. At the same time, we did not want the problem set questions to be so difficult that students would need to heavily rely on outside resources. We decided that recitation (optional small group problem-solving sessions run by Lou four times a week) is the ideal environment to prepare students for difficult questions on the problem sets.

Action: Split up past recitation questions, problem sets, and exam questions among the three student consultants, and we each flagged problems that were confusing or did not help achieve learning goals. We also identified questions that we thought should be moved to one of the other categories and suggested new and improved questions when applicable.

***Need*:** Exams were scheduled at very busy times in the semester and students were often stressed.

Discussion: Together we went through the syllabus and identified when it would be best to have an exam to conclude a section of the course and begin a new one. We then examined the academic calendar and tried to find times that fit both the flow of the course and the students' needs.

Action: Determined exam dates for the following semester.

Week 6: Lecture Notes

Need: Students commented that it would be useful to highlight key concepts and topics covered in each lecture.

Discussion: After reflecting on the semester as a whole, we reviewed the syllabus and discussed the flow of the course. Looking back, we were clearly able to see the progression and flow of material; however, we thought it would help students if they could see the progression more clearly as they moved through the semester. We therefore brainstormed methods to make this flow more apparent and decided to make the lecture design more transparent to the students.

Action**:** Clearly articulated key concepts/topics from each lecture and created a list of objectives ("by the end of the class you will be able to…") to be shared the students at the beginning and end of each class.

Week 7: Reflection on Process

Need: Time to reflect on and articulate how the revision process changed our perspective as a teacher/student.

Action: Discussed process and outcomes of the student-led revision experience (see details below).

Outcomes for Student Consultants *(Anna, Noah and Saadia)*

As students going into this experience, we were fairly confident that a major outcome would be an improved course. What we didn't expect was that the experience would have such a profound impact on us. At the end of the process, our professor asked us to reflect on the process and what we gained from the experience. Our responses focused on the following three themes:

> (1) a deepened understanding of what it takes for faculty to prepare to teach a course and how students can make the most out of courses in which they enroll;
>
> (2) reinforcement of fundamental concepts in organic chemistry; and
>
> (3) an opportunity to meld interests in chemistry and education.

(1) Deepened Understanding of What It Takes to Prepare and Engage in a Course

We valued the opportunity to talk directly with our professor and fellow students about general aspects of course design. We grappled with deciding how to teach in a way that challenges students who understand the material, while simultaneously ensuring that struggling students aren't left behind. We discussed the pros and cons of many different aspects of the course. For example, we considered the benefit of the daily "check-your-understanding" reading quizzes. While they take extra time, we decided the self-check process was valuable, and encouraged students to do the readings. We also discussed broader questions, such as what is the ideal median of a test?

Of course, there are no quick answers to questions like this about teaching. But we think the process of engaging with professors in dialogue about course construction is beneficial. As Anna noted in her post-revision reflection:

> [The process] gave me a sense of agency on the level of the course and the Chemistry Department as a whole. I think it is valuable for students to feel invested in this way, so was grateful for the opportunity to contribute to these conversations about *Organic Biological Chemistry*.

The revision process was enlightening in terms of understanding how much goes into teaching a class and how as students we can make the most out of a course by recognizing how different resources come together to provide a framework for learning. We have been able to apply this understanding to make the most of our other courses as well. In his reflection, Noah wrote:

> Discussing what we aim students to take away from problem sets versus recitations made me aware of the different tools that professors have to enable students to engage with the material. With these new insights, I am able to contextualize different assignments in other courses for the maximum enrichment.

(2) Reinforced Fundamental Concepts in Organic Chemistry

Often throughout this experience, we had to deliberate on how to structure the course through the syllabus in order to facilitate learning. Doing so required us to compartmentalize our understandings and allowed us to make connections that we had missed when we first learned the material.

Additionally, needing to consider the material at different levels and having to think whether a question truly gets at a critical concept reinforced our knowledge. When we first learned the material, we were stuck at whichever level we each were able to understand it; however, this experience has allowed us to zoom in to the specifics but also see the bigger picture of the course in context. One way we reinforced fundamental concepts was by brainstorming topics for the new "key concept" questions for the problem sets. Thinking about whether a question truly gets at a critical concept reinforced our knowledge and allowed us to think broadly about organic chemistry. Working with the lecture notes and quiz questions was also particularly helpful in this regard. Addressing these areas required us to reexamine our understanding and allowed us to make connections that may have missed when we first learned the material. Anna noted that while digitalizing the lecture notes and sorting quiz questions:

> I was able to unpack each topic, lay all my knowledge on the table, and reassemble it in a way that further integrated the information. I think my understanding of organic chemistry improved because I was able to integrate knowledge and concepts that were cemented at a later stage in the semester and reapply them to concepts learned towards the beginning.

When we first learned the material, we were only able to apply the knowledge we had accrued up to that point in the semester; however, when we revisited the material as consultants, we were able to see everything in light of the entire body of knowledge gained throughout the course.

(3) Provided an Opportunity to Meld Interests in Chemistry and Education

Those of us interested in both science and education also noted how this was a unique opportunity to meld these interests in a formal way. We gained insight into the art of crafting a syllabus that supports students as they engage in the material, and we had the chance to consider what kinds of techniques should be taught when.

One of our goals was to ensure that the material was presented in a logical, organized way that would allow students to see connections and build on previous knowledge so that they build a strong base of understanding and feel empowered to tackle the next section. We began advancing this goal by discussing organization and flow of the coursework. As students in the course, we had felt that topics generally seemed to flow naturally as we progressed through the semester. In working to revise the course, we began to fully appreciate that a systematized order of organic chemistry is not self-evident. There are many ways to organize a syllabus of organic chemistry: by reaction type, by functional group, by nucleophile.

Likewise, questions of teaching particular techniques need to be asked in relation to questions regarding organization of topics. Should spectroscopic techniques be taught in one section, or distributed throughout? Thinking about questions like these pushed us to step back and identify the threads of organic chemistry and how they can be combined to provide a central avenue of learning.

While there are many seemingly disparate topics and reactions, our goal was to allow students to see the big picture and to be able to understand how topics relate. This is not a simple task. It takes skill to craft a syllabus that makes organic chemistry accessible, rather than dauntingly complex.

Conclusion

Lou's reflections: The process of working in collaboration to revise *Organic Biological Chemistry* was quite rewarding, and we ended the semester-long revision process with a newfound feeling of mutual understanding and admiration. As the professor, I was able to see the class with beginners' eyes and through the lens of my audience. I gleaned glimpses into what they put into a class and how they approach learning such voluminous and challenging material. As a team, we all struggled through difficult concepts, like how to link assessment to the course objectives, and then made rational changes to the course structure accordingly. We all cared so deeply about "getting it right" and our conversations were at times frustrating, but always invigorating. We created a bond through our shared interest and investment. The teaching consultants each derived their own particular benefits:

Anna's reflections: Going into the process, I hoped that Lou would find our feedback and perspectives a useful tool to assist in shaping the course. As a group, I think we were successful in that regard. I had also expected to deepen my understanding of the material, both through increased exposure and by considering how topics relate and how to let the syllabus and course structure allow students to see connections and parallels. I did not foresee, however, the extent to which participating in this process made me feel more connected to the course and the Chemistry Department as a whole. I think that student participation in course design could be a powerful pedagogical tool that urges students to invest in their education and take responsibility for their

learning. Being able to work with my professor and peers in this setting was both fun and rewarding. In order to stay in touch with the course, I worked at CQC as a teaching assistant/peer tutor the next fall, when Lou taught the course for a second time. This experience gave me the opportunity to see how some of the changes were implemented. For example, students often noted that the new "key concept" questions on their problem sets could be particularly tricky, as they had to use words, instead of structures or mechanisms, to describe the chemistry. Indeed, the ability to *explain* rather than just *do* organic chemistry is critical to long-term understanding. The key concept questions were working just as intended! I loved taking part in CQC. It was a perfect opportunity to both stay in touch with the course and get to know the new group of students as they navigated the difficulty and excitement of learning organic chemistry.

Noah's reflections: In my application for this position, I stated that my main motivation was to help future *Organic Biological Chemistr*y students. I also expressed hope that this experience would help me find new insights in the material and enhance my capability to tutor students in chemistry in the future. These latter two goals turned out not to be mutually exclusive. Discussing the course with my peers and professor in a critical manner provided a conducive medium to exchange our different perspectives and contextualizations of the material. This allowed me to help students see the forest through the trees throughout the course and ensure that they thought about how the course was building up on itself to the material at hand. I was also able to use the discussions that the revision team had about learning objectives to guide students towards realizing these goals, pushing them beyond just getting a good grade on the problem set. I think that the students indeed benefited not only by having tutors that engaged in the course building/revision, but also by having the professor incorporate more intimate feedback from previous students.

Saadia's reflections: One of the reasons I was intrigued by the peer-led course revision position was because it was a great opportunity to combine my love for chemistry and interest in education. It also gave me a unique opportunity to think from different points of view: as a student and, during course revision, as a teacher. Through the process of transcribing and reorganizing lecture notes based on key concepts, I was able to re-engage with the course material in a new way: I constantly thought about the flow of the lecture and if the chronological order of introducing the material made sense. Through this experience, I also gained a newfound appreciation for professors and the amount of work they put into teaching their courses. I noticed little details like how effort was put in putting discoveries in context and giving background information to keep lectures interesting and students engaged. Coming out of this experience, I feel like I have grown as both a student and a teacher. As a peer tutor, I had some experience tutoring students in chemistry before. However, through helping in the peer-led revision process, I learned new techniques to help present material to my fellow peers as well. Overall, this experience allowed me to not only share my input and perspective, but also deepened my understanding on the act of teaching. I look forward to integrating my experience in the future to better help students and teachers in the community.

***Postscript** (Lou)*

I have now taught the course for a second time, incorporating the changes stemming from our student-led course revision. I felt empowered teaching a course with my newfound clarity of

purpose. I sensed a deeper connection with my students born from the bond with my student consultants. I consciously created an environment of pedagogical transparency and fostered an environment in which students could come to me with continual feedback and suggestions to make the course stronger. I felt like I was a part of a team, and that I was working along-side my students to achieve the course objectives. This experience taught me that the nexus between "teacher's perspective" and "students' perspective" creates fertile ground for learning.