

Just-in-Time Teaching in Organic Chemistry
Jennifer Muzyka
Centre College, Danville, KY 40422

Abstract. In the Just-in-Time Teaching approach, a faculty member assigns readings to students before every class. After the students have done the daily reading, they access a short reading quiz on a course management system (e.g., Moodle). The faculty member uses student responses to the quiz in the preparation of the day's class material and is able to tailor his or her explanations to target specific student questions or confusion. This paper describes the use of this approach to engage students in chemistry classes at Centre College.

When I began teaching, my approach was to teach the way I had been taught - mostly lecture punctuated by questions to provoke students to think. Along the way I realized that many students were very quiet in class and I could not tell how well they were absorbing the material. That lack of feedback from quiet students led me to begin using clickers so that I could assess how well students understood the new concepts we were discussing. Later I read about a twist on the usage of clickers during class called peer instruction. In this approach, students answer each clicker question twice. Their first answer reflects their individual thoughts about the question. Before answering the question a second time, students are encouraged to discuss the issue with a classmate who disagrees with them. Clearly the students benefit from discussing concepts with their classmates because they are actively putting their thoughts into words as they wrestle with the challenging topics. More recently I began using the pedagogical approach called Just-in-Time Teaching, which involves reading assignments and associated reading questions that students are required to answer before class. The faculty member uses student responses to the reading questions to develop the plan for each class period.

Faculty choice of pedagogical method depends on the learning goals for the course, based on our understanding of the challenges students experience attaining the course learning goals. Goals for students include acquiring information as well as learning how to apply that information to new situations. A third goal is one that students might not always recognize – developing lifelong learning skills.

The struggles students have gaining meaning through reading of technical material are well known and have been documented.¹ Not all chemistry students will become professional chemists; however, all students will need to be adept at reading-to-learn in their career path. Thus, I am committed to guiding my students as they develop necessary skills to read chemistry textbooks and occasional articles from the primary literature. Other chemists have emphasized the importance of having students read their textbooks before class. Collard et al. have reported the use of pre-lecture homework assignments to encourage students to read the textbook before the material is later covered in class using a traditional lecture format.²

In most classrooms, instructors lecture on course material, realizing that students are being exposed to the material for the first time during that class period. Later, the students practice applying the concepts as they struggle individually with homework sets or suggested problems. The flipped classroom approaches alter this tradition, requiring students to begin the process before the concepts are discussed in class. In this way, the in-class discussions are more sophisticated. More importantly, the students can tackle problems of greater complexity during class with the instructor present to provide guidance. Now, instead of students experiencing confusion for the first time outside of class as they struggle with homework problems, the instructor is present to guide students through the difficult concepts during class. To hold students accountable, I require students to answer questions on the assigned reading via an online quiz that they access via Moodle. Prior to class, student understanding can be assessed and misconceptions identified from student responses to reading questions.

Some students resist innovative pedagogical methods because they perceive that being actively engaged during class involves more effort than taking notes from a professor's lecture. In order to generate student buy-in for these different approaches, we spend time during the first class meeting of the term discussing the learning goals of the course and how best to be successful in the course. We discuss what types of learning activities are best done independently or with assistance from their colleagues and the instructor. Figures 1 and 2 display clicker questions described by Smith that we use to initiate and guide discussion about learning goals for the course.³

Thinking of what you want to get out of your college education and this course, which of the following is most important to you?

- A. Acquiring information (facts, principles, concepts)
- B. Learning how to use information and knowledge in new situations
- C. Developing lifelong learning skills

Figure 1 - First day clicker question about learning goals

Of these three goals, which do you think *you can make headway on outside of class* by your own reading and studying?

- 1. Acquiring information (facts, principles, concepts)
- 2. Learning how to use information and knowledge in new situations
- 3. Developing lifelong learning skills

Figure 2 - First day clicker question about activities outside class

Just-in-time teaching was developed by physics educators, and it has been described in two books that I found to be valuable resources during my transition to this pedagogical method.^{4,5} For most class periods, I assign a few sections of the textbook for students to read. After reading these sections, the students answer a couple of questions about the content covered in the reading. The third question always asks students what they found most confusing or most interesting in the reading assignment.

Moodle's quiz activity is ideally suited for these JITT reading quizzes. When the quiz is first created, it is possible to set up a time period when students are allowed to access the quiz. The question bank can be organized into categories in order to facilitate the reuse of questions in subsequent offerings of a course. Lastly, it is straightforward to grade all student responses to a given question at one time.

I use student responses to the reading questions in order to develop presentations for the upcoming class period. Students receive full credit for grammatically correct answers even if they have incorrect chemical statements, because the goal of the reading is to identify misconceptions so that they can be addressed during class. This approach allows me to determine points of confusion even from the most reticent students, who may never speak aloud in class. (See Figure 3 with sample question and student responses.) Another benefit of this method is the fact that we spend much less class time defining new terms. When the new terms are particularly confusing, we do spend class time discussing their definitions. Since students have already grappled with these concepts on their own, the class discussion is more productive. It is especially important that students have seen the words prior to class. In the physical sciences, students are often learning a new language.

Describe what is meant by the term conformations. Why is this concept important in organic chemistry?

- A conformation is a different arrangement of atoms that results from bond rotation. Because molecules can rearrange themselves via bond rotation, different conformations of molecules will be more or less stable under any conditions.
- Conformations are the different arrangements of atoms that result from bond rotation. This concept is important because it allows you to visualize the atoms in 3-dimensional space. It allows you to address the true spatial arrangement of atoms in molecules.
- Conformation is a different arrangement of atoms as a result of bond rotation. Because of the sigma bonds between a carbon-carbon single bond are cylindrically symmetrical, rotation is possible around carbon-carbon bonds in open chain molecule. Different conformations have different energies--for example, staggered conformations have lower energies than eclipsed conformation.

Figure 3. Reading question with sample student responses

I find that the just-in-time teaching method facilitated using Moodle presents benefits for both students and faculty members. One of the most powerful benefits of this approach is the ability to provide individualized feedback for students who are too shy to speak aloud in class or visit office hours. Another important benefit to students is that they progress at a steady pace as the class progresses rather than slipping behind and then cramming right before a test. We observe improvements in students' reading skills with this approach, consistent with goal of them becoming independent lifelong learners.

Instead of spending time defining terms, class time is focused on areas of student confusion. Students realize that familiarity with the basic terms prior to class is expected. Significantly, students recognize that their ability to read and comprehend technical material is improving as the course progresses. Moreover, immediate feedback on what students find challenging enables instructors to address student misconceptions as soon as they arise. These changes in course structure provide

enhanced opportunity for active learning methods⁶⁻⁸ such as peer instruction⁹⁻¹³ and other small group activities¹⁴⁻¹⁷ without sacrificing content in the course overall.

Each class is different, and class discussions are shaped by student interest. Perhaps the most important benefit to the JITT method is that class discussions are more stimulating because students are primed and ready to talk. The two-way online feedback helps build rapport between instructor and students fairly early during the term.

A typical class meeting will start with a PowerPoint slide containing the text of the first question from the reading quiz. Next, we'll see a slide with one student's answer to that question. In the flow of the presentation there will be slides containing questions that students asked in their responses to question 3. Often these questions relate to particular examples from the text. I will display the relevant graphic or table to facilitate discussion of it. After the concept has been thoroughly discussed, students will individually answer a clicker question about the topic. Without letting students see the range of responses to the first round of polling, I encourage them to discuss the question with a neighbor and to answer the question again. This discussion of the question and second polling with clickers is sometimes called peer instruction. It has been demonstrated to produce gains in student learning.^{18,20}

It is important to acknowledge the costs associated with this pedagogical approach. Developing thought provoking reading questions takes an investment of time, and the semester goes more smoothly if the questions have been developed before the beginning of the semester. Reading student answers and responding to them takes a lot of time.

Students in the organic chemistry courses taught by three different faculty members responded to a survey about the teaching methods used in their courses. Individual instructors use different pedagogical approaches, one using JiTT with peer instruction, one using small group work and occasional reading questions, and one using mostly lecture. Student responses to the survey are summarized in Table 1. Students were asked to rate the relative impact of each factor on their overall learning in

the course. Responses were on a scale of 0 to 7, with 0 being not applicable, 1-3 being negative, 4 being neutral, and 5-7 being positive. The survey results indicate that students generally affirmed the effectiveness of the teaching methods to which they were exposed. In addition to these questions requiring numerical responses, students were asked to identify the activities that had the strongest effect on their learning. This question is where the variety in pedagogical approaches had the most significant impact. Students exposed to Just-in-Time teaching with peer instruction displayed more variety in the range of their answers, with clicker questions and discussions of the clicker questions playing an influential role for these students. Table 2 displays representative student responses from the students in the JiTT course to the question about which activity had the strongest effect on their learning.

Table 1. Student survey about effectiveness of different pedagogical approaches.

Factor	JiTT with peer instruction		Some reading questions and small group work		Mostly lecture	
	Mean ± SD	Pos / Neg	Mean ± SD	Pos / Neg	Mean ± SD	Pos / Neg
Professor	6.24 ± 0.97	92% pos / 2% neg	6.64 ± 0.64	100% pos / 0% neg	6.28 ± 0.83	97% pos / 0% neg
Friends/informal groups	5.20 ± 0.94	80% pos / 2% neg	5.85 ± 0.96	94% pos / 0% neg	5.52 ± 1.48	83% pos / 3% neg
Course organized groups	4.12 ± 2.45	60% pos / 0% neg	4.36 ± 1.87	52% pos / 0% neg	4.97 ± 1.47	66% pos / 3% neg
Evening chemistry tutoring	1.48 ± 2.28	12% pos / 0% neg	1.55 ± 2.62	18% pos / 0% neg	1.41 ± 2.04	10% pos / 7% neg
Lecture – overall	5.59 ± 1.29	85% pos / 10% neg	6.28 ± 0.80	100% pos / 0% neg	6.24 ± 0.82	97% pos / 0% neg
Clicker questions	5.69 ± 1.22	81% pos / 5% neg	0	NA	0	NA
Discussing clicker questions	5.92 ± 1.10	88% pos / 2% neg	0	NA	0	NA
Exams	5.51 ± 1.11	83% pos / 7% neg	5.42 ± 1.02	85% pos / 3% neg	5.52 ± 1.22	83% pos / 7% neg
Quizzes	5.69 ± 0.89	90% pos / 0% neg	5.15 ± 1.67	79% pos / 6% neg	1.55 ± 2.47	17% pos / 3% neg
Reading questions	4.88 ± 1.45	67% pos / 12% neg	3.31 ± 2.65	53% pos / 0% neg	1.17 ± 2.33	21% pos / 0% neg
Homework/exercises	5.05 ± 2.09	74% pos / 0% neg	6.36 ± 0.85	97% pos / 0% neg	6.52 ± 0.62	100% pos / 0% neg
Textbook	5.19 ± 1.03	79% pos / 5% neg	4.55 ± 1.72	58% pos / 15% neg	3.86 ± 1.33	28% pos / 21% neg
Spectral Zoo	5.45 ± 1.40	79% pos / 2% neg	3.27 ± 2.48	39% pos / 3% neg	0	NA
Reaction Zoo	5.52 ± 1.87	79% pos / 0% neg	4.03 ± 2.46	61% pos / 3% neg	0	NA
Small group work	5.50 ± 1.05	83% pos / 2% neg	4.91 ± 1.53	73% pos / 0% neg	3.24 ± 2.75	45% pos / 7% neg
Lab – overall	5.41 ± 0.80	88% pos / 0% neg	5.12 ± 1.17	73% pos / 9% neg	5.55 ± 0.85	90% pos / 0% neg
Lab manual	5.14 ± 1.01	67% pos / 2% neg	4.88 ± 1.47	67% pos / 12% neg	5.10 ± 1.27	79% pos / 0% neg
strongest	9 – lecture 8 – clicker questions 6 – discussing clicker questions 6 – group activities 5 – reaction zoo 5 – homework/exercises 4 – quizzes 3 – spectral zoo 2 – reading questions 1 – lab 1 – exams 1 – instructor		15 – lecture 13 – homework 5 – instructor 3 – group activities 2 – exams 1 – quizzes 1 – lab 1 – office hours 1 – evening chemistry tutoring		13 – homework 9 – lecture 3 – instructor 3 – group activities 2 – exams 1 – quizzes 1 – lab 1 – office hours	

Table 2. Comments about activities that most strongly affected student learning.

About reading questions:

- The reading questions made the reading more understandable. It helped to point out the big picture things.
 - The readings really helped me understand the material. I think Dr. Muzyka's approach of reviewing the readings in class was especially useful because after we reviewed the reading, I could understand it very well and the book became a greater resource.
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About peer instruction:

- Discussing clicker questions was very helpful b/c it helped me understand why I was wrong and how to get to the correct answer.
 - I also think more clicker questions should be incorporated into the course, they were great. You had a chance to think it through alone & then discuss with others. If you made mistakes the first time, it allowed you to understand why the correct answer is what it is.
 - The clicker questions, in conjunction with lecture, were very helpful because we were able to apply what might otherwise be only theoretical concepts, work through them individually and in groups, and then have them explained to us.
 - Clicker questions had the most impact & really helped me to gauge how I was understanding the material in class. Discussing them also helped me to get clarity & better understanding.
 - Clicker questions and the following group discussion really keep you engaged and thinking.
 - The clicker questions/along with the quizzes allowed me to see what I was still struggling with before the test. With clicker questions, we were able to discuss it with others and get a better point of view.
 - Small group discussion definitely helped me learn, especially with clicker slides. Having to articulate why you think something really helps solidify it in your brain, or at least it does for me.
 - Clicker questions and discussions --> I was able to apply what I had read the night before to a question and discussing it with others really made me critically think about my decisions.
 - Probably the clicker questions/ discussions. They were usually questions that generally had me confused but were able to point me in the right direction with discussion.
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About group activities:

- Group activities, it helps me to talk things out & see problems rather than to read.
 - Small group packet work - I was able to work through problems at a more suitable pace!
 - The small group work, b/c it made me be the most active and engaged in learning the material b/c we had to teach it to our peers as we did the packets.
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In conclusion, student responses to our survey indicate that they have embraced the pedagogical approaches used by instructors as long as the students understand the reasons for the method chosen. I believe that offering a variety of pedagogical methods encourages students to become independent learners by developing their reading skills and their metacognitive skills. I feel strongly that the benefits outweigh the costs associated with this pedagogical approach. I encourage other faculty members to

consider this method to actively engage students and help them develop as independent learners.

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