In-Class Versus At-Home Quizzes: Which is Better? A Flipped Learning Study in a Two-Site Synchronously-Broadcast Organic Chemistry Course

By Michael A. Christiansen,[a,*] Alyssia M. Lambert,[b] Louis S. Nadelson,[c] Kami M. Dupree,[a] and Trish A. Kingsford[a]

[a] Utah State University, Uintah Basin Regional Campus: 320 North Aggie Blvd, Vernal, UT, 84078, U.S.A. Fax: (435)-789-3916
* Phone: (435)-722-1761; email: m.christiansen@usu.edu
[b] Skagit Valley College: 2405 E College Way, Mt Vernon, WA, 98273, U.S.A.
[c] Utah State University, Emma Eccles Jones College of Education & Human Services, 2805 Old Main, Logan, UT, 84322

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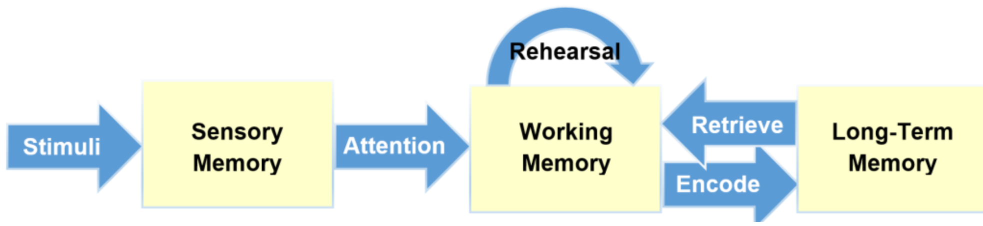
ABSTRACT

We recently shared our design of a two-semester flipped organic chemistry course, in which we gave students in-class quizzes to incentivize attendance and watching the lecture videos in advance. With a second iteration, we planned to make the video-watching experience more engaging. We accordingly hypothesized that if students completed short at-home quizzes while watching the videos, then attentiveness, engagement, and learning would increase. We tested this with a later section of the course, dividing the material into 13 units. For units 1-6, we gave in-class quizzes; for 7-13, quizzes were at home. Although units 1-6 and 7-13 covered different material, we were nonetheless surprised when students' average quiz scores decreased for the take-home quizzes, because they did not have a time limit and were open-book, unlike the in-class quizzes. Anonymous survey feedback showed a strong preference for quizzes in class and indications that take-home quizzes demotivated attendance and pre-class watching of the videos. Thus, for analogous flipped-course designs in chemistry, we recommend an in-class quizzing strategy over take-home quizzes to positively affect engagement, learning, and attendance. Of note, this course was synchronously-delivered to two groups of students at geographically-distinct satellite locations.

INTRODUCTION

As a broad theoretical framework, *cognitive information processing* (CIP) *theory* proposes a semi-computer-like model by which people learn, retain, and access information.[1] At its core (see Scheme 1), CIP theory suggests that new data (or "stimuli") trigger "sensory memory," whereupon learners decide (or "select") which data merit attention.[2] Data that pass this filter move into an area called "working memory," where the learner digests them through a process called "rehearsal." As "rehearsal" matures, it becomes "elaborative rehearsal" or "encoding", which encompasses repetition, connectivity, memorization, and so forth. Data then transfer into "long-term memory," for later retrieval.[3] Because learners' attention spans have limits, learning at each stage occurs in small chunks.[4] Ideally, this happens best if each step, particularly "encoding," is given adequate time.[5] Obviously, limitless time is impossible. However, the theory at least validates teaching practices that work toward maximizing students' time to absorb new information "chunks" and then digest them at their own pace through "elaborative rehearsal."



Scheme 1. Simplified model of *cognitive information processing* (CIP) theory, adapted from ref *1*.

From our observations, flipped teaching is a pedagogical framework that seems to approach this ideal of selective, semi-self-paced learning. In flipped courses, lectures get pushed outside of class as short, targeted, indexed videos online,[6-8] which students watch at home. This lets them better control what they learn and when they learn it, allowing them to modify the order, frequency, or pace of lecture-watching outside of class and then advance or review the parts they need most. In prior work, we found that flipping reduced our total formal lecture time by 56–67%, relative to our traditional-lecture (TL) format.[9-10] We therefore note that this method gives students more time for "elaborative rehearsal" by decreasing total lecture minutes, as well as more control to process new information in "chunks," via navigable videos. Furthermore, as students in our flipped classes spend in-class time doing problem sets in assigned groups (problem-based learning[11]), it creates a classroom environment that leverages the advantages of Peer Instruction[12-14] and elements of just-in-time-teaching (JiTT).[15-17]

To explain the latter, JiTT (developed by Gregor Novak in the late 1990s) involves a feedback loop through which: (1) students use reading, web-based, or other materials to prepare for class; (2) they then submit answers to complex problems online *before* class; and (3) instructors adapt class activities to focus on areas of greatest confusion, based on student submissions.[18] Our course structure is really more of an *adapted* JiTT approach, through which students do step (1), primarily by watching assigned content videos before class, but do not do step (2) in advance. Instead, student groups submit problem sets and questions *during* class as they work together, and the instructor responds immediately. Thus, step (2) occurs individually in groups or in-person, as class unfolds. As the flipped format offloads course content to videos before class, formal in-class lectures are replaced with on-demand mini-lectures to address areas of greatest confusion right when students face them, thereby realizing an adapted form of step (3). Because the flipped classroom increases students' control over the time and speed with which they digest content, and peer-groups provide incentive to not get behind, we envisage that these elements may combine to yield greater "encoding" and consequent conversion of "working" into "long-term memory."

Flipped learning has received increased literature scrutiny in recent years, from a spectrum of fields and a variety of practitioners.[6-9,19-26] While the basic formula remains the same (content-delivery outside of class, higher-learning in class), pedagogical details both in and outside of the classroom vary. For this disclosure, we will focus primarily on what students in flipped courses are asked to do along with their video-watching. Within this arena, Flynn reported having her students watch videos or read textbook excerpts outside of class, followed by a pre-class test.[19] In Weaver and Sturtevant's flipped chemistry course,[20] as well as Fautsch's,[21] students watched lecture videos and then took quizzes online. In Jensen's flipped biology class,[22] students answered intermittent online questions while watching videos, before the videos would advance. For Ryan and Reid's general chemistry course,[6] video-watching was complemented with a weekly online homework assignment. Duffield,[23] in contrast, assigned students to watch videos and then fill out post-video “reflections” online. Some practitioners report having students watch videos outside of class and then take *in-class* quizzes,[24] while others assign students to view videos with no other specific outside-of-class activity mentioned.[8-9,25] For these cases, it seems likely that instructors expected students to take notes or read complementary sections of their textbooks while watching videos, but most do not explicitly state this. For well-known flipped educators Bergmann and Sams, students are taught and asked to use the Cornell notetaking method while watching videos.[26]

There obviously exists a variety of approaches within the flipped domain. That we are aware, no one has systematically changed their outside-of-class format midterm with a single cohort of students, for the purpose of comparing and contrasting results. We reasoned that doing so might help practitioners choose between possible outside-of-class strategies. Based on prior work, we centered our study on the variable of in-class versus at-home quizzes. In our previous flipped courses,[9] we assigned students to watch lecture videos outside of class and spend in-class time doing problem sets in assigned groups. We used weekly in-class quizzes to incentivize attendance and encourage students to watch the videos before class.[9] Our students’ high quiz performance (89.4% average) indicated that they generally did. As learning and engagement positively correlate,[27-32] we reasoned that if our course were restructured to increase student attentiveness *while* watching the videos, then learning would improve. For our prior study,[9] students were encouraged to take notes while watching the videos, but there was no follow-through to see if they did. We accordingly hypothesized that if students were given short quizzes to complete while watching the videos outside of class, then their attentiveness and engagement with the videos would increase, which would ultimately improve learning. From this hypothetical foundation, we formulated the following research questions:

Q1: Which approach, quizzes in class or at home, will yield higher grades?
Q2: Which approach, quizzes in class or at home, will students prefer?

EXPERIMENTAL SECTION

Note: This study was reviewed and preapproved by an Institutional Review Board (IRB).

A Two-Site Broadcast Course

Our four-credit, first-semester, flipped organic chemistry course differed from that of our previous study[9] because it was simultaneously delivered to two locations. Group 1 (face-to-face, or “F2F” students) included those attending in-person with the instructor, while Group 2 (distance students) attended at a distant satellite campus. Through the public *Utah Education Network*,[33] the class was broadcast to distance students, who could see and hear the instructor, lecture slides, and overhead ELMO Cam notes in real-time on a projected screen at the front of their room. The distance classroom was equipped with microphones, allowing distance students to ask questions live and participate in real-time discussions. At the origination site, the instructor could see distance students on a monitor at the back of the room and direct a facilitator to toggle between video-capture of the instructor, lecture slides, or ELMO Cam notes. Though unusual, this type of live, multi-site, interactive broadcast teaching is becoming more common in North America, as universities expand programs across geographically-dispersed satellite-campus networks.[34-36] The topic of flipped learning in such settings is highly under-addressed in current literature.[37-38]

Population Studied

Though atypical for traditional university settings, small class sizes are not abnormal in the realm of multi-site, satellite-campus teaching, especially in rural areas.[35,39] Our study involved twelve students (N_{F2F} = 7, $N_{Distance}$ = 5), whose demographics are summarized in Table 1, with F2F and distance students' data being separated for clarity.

Table 1. Demographic Data for Organic Chemistry Face-to-Face and Distance Students

Item	Group 1, Face-to-Face	Group 2, Distance
N	7	5
Gender	2 Female, 5 Male	2 Female, 3 Male
Mean Age, Years (SD)	24 (3.5)	25 (8.3)
Ethnicity	6 White, 1 Latino	4 White, 1 Latino
Major	Biology: 5 Undeclared: 2	Biology: 2 Psychology: 1 Chemistry: 1 Education: 1
Mean GPA (SD)	3.46 (0.42)	3.60 (0.27)
Median GPA	3.55	3.80
Mean Chem GPA (SD)	3.34 (0.22)	3.43 (0.36)
Median Chem GPA	3.42	3.33

Course Design

Students watched 79 out-of-class videos (average length of 9.5 minutes),[40] following a schedule posted on Canvas, our course management system.[41] Class meetings involved two weekly 100-minute sessions and covered about one chapter-unit per week. Videos were made using Camtasia Studio 8.3 and included PowerPoint lectures with picture-in-picture footage of the narrating instructor, or of the instructor solving problems on a board.

As Table 2 summarizes, the semester covered 13 total units. For each chapter during units 1-6, students were given closed-book, 10-minute quizzes at the start of class about the videos they watched in advance at home. For units 7-13, students accessed and printed off their quizzes in advance, outside of class. They then filled out the quizzes *while* watching the videos, with an open-book format and no time limit. Once complete, students submitted their final quiz answers through Canvas. Quiz problems were drawn from an 895-question database we created for the class.

Students spent in-class time clustered in assigned groups, working on problem sets (~28 questions per set),[42] which included mixed-format (open-answer, multiple-choice, etc.) questions created by the instructor or modified from our textbook's published question databank. During class, the instructor intermittently observed student work. For distance students, this was done by checking in over the microphone every five to seven minutes, often with queries such as: "Group 1, how are you doing?" "What questions do you have?" "What parts are you finding most challenging?" If no one voiced a question, then the instructor invited all participants (F2F and distance) to keep working and ask when confusion arose. Otherwise, the instructor would wait another five to seven minutes and then repeat the cycle. As questions came in, the instructor either directed students to helpful resources or gave short mini-lectures to clarify confusion.

On average, students had about one week per problem set. Throughout the semester, they could submit problem sets at any time until the due date and get feedback without losing points. Distance students did this by either having their local facilitator scan pages, or by using smartphones to photograph pages, which they emailed to the instructor. The instructor then gave feedback straightway over the ELMO Cam, or made annotations to students' submissions on his computer and replied to the entire distance group immediately through email. This feedback question-answer loop between the instructor and students (both F2F and distance) permeated the bulk of class time.

In total, students took 13 quizzes (10% of their grade, lowest score dropped) and completed 13 problem sets (20% of their grade, lowest score dropped). They also took five exams (four midterms and a comprehensive final, the lowest midterm was dropped), which accounted for 67% of their grade, and a formative entrance exam, worth 3% of their grade. Each group member received the same problem set grade. However, to encourage active contribution to group work, students were asked to anonymously submit "peer grades" for each group member at the end of the term. These peer grades were then used to adjust individual problem set grades, as described in our previous study.[9]

Table 2. Flipped Organic Chemistry Course Structure

Chapter or Unit		At Home	In-Class
1	Chemical Bonding, Acids and Bases	Watch videos	Quiz 1; Problem Set 1
2	IUPAC, Chemical Structure, Physical Properties	Watch videos	Quiz 2; Problem Set 2
3	Intro to Alkenes	Watch videos	Quiz 3; Problem Set 3
Exam 1			
4	Reactions of Alkenes	Watch videos	Quiz 4; Problem Set 4
5	Reactions of Alkynes and Intro to Synthesis	Watch videos	Quiz 5; Problem Set 5
6	Stereochemistry	Watch videos	Quiz 6; Problem Set 6
Exam 2			
7	Electron Delocalization and Diels-Alder Chemistry	Watch videos; Quiz 7	Problem Set 7
8	Substitution Reactions	Watch videos; Quiz 8	Problem Set 8
9	Elimination Reactions	Watch videos; Quiz 9	Problem Set 9
Exam 3			
10	Reactions of Alcohols, Ethers, Epoxides, Amines, Sulfides, and Thiols	Watch videos; Quiz 10	Problem Set 10
11	Organometallic Chemistry	Watch videos; Quiz 11	Problem Set 11
12	Radical Reactions	Watch videos; Quiz 12	Problem Set 12
Exam 4			
13	Spectroscopy	Watch videos; Quiz 13	Problem Set 13
Comprehensive Final Exam			

RESULTS AND DISCUSSION

Student Scores and Quantitative Findings

As Table 3 indicates, problem set averages (row 2) remained similar through units 1-6 and 7-13, while exam averages (row 3) dropped markedly for F2F (not distance) students in units 7-13. Counterintuitively, students' mean quiz scores (row 1) decreased for at-home quizzes (units 7-13), relative to in-class quizzes (units 1-6). This is surprising, as in-class quizzes (units 1-6) were timed and closed-book, while at-home quizzes had no effective time limit, and students could use any resource while taking them.

Table 3. Comparison of Quiz, Problem Set, and Exam Average Scores

Item		Units 1–6, In-Class Quizzes		Units 7–13, At-Home Quizzes	
		Group 1, Face-to-Face[a]	Group 2, Distance[b]	Group 1, Face-to-Face[a]	Group 2, Distance[b]
1	Mean Quiz Grades, % (SD)	85.71 (24.31)	88.67 (13.58)	70.44 (32.54)	71.76 (25.64)
2	Mean Problem Set Grades, % (SD)	93.20 (18.48)	94.50 (8.84)	99.00 (2.04)	93.76 (8.32)
3	Mean Exam Grades, % (SD)	85.05 (13.82)	86.57 (14.81)	64.71 (23.58)	82.40 (11.88)

[a]*N* = 7. [b]*N* = 5.

We wondered: were the apparent differences in the academic achievement indicators for the between F2F and distance students significant? To answer this, we used delivery method (e.g., F2F and distance) as the factor, or independent variable, and academic measures as the dependent variable. We started our analysis by examining student outcomes on quizzes 1-6 and 7-13 by first computing the average outcome value for students' scores on quizzes 1-6, and then doing the same for quizzes 7-13. Using the academic achievement indicators as dependent variables, we conducted an independent samples tests for each measure. Because of our limited sample sizes, we ran Mann-Whitney *U* and Wilcoxon between-group comparisons. Both nonparametric statistical methods are suited for small sample sizes that cannot be effectively tested for distribution assumptions (e.g., normality). (See the Supporting Information for full details of our statistical analysis.) While the nonparametric tests reduce the power of the analysis, they are effective for testing between-group differences. No statistical difference was observed between the F2F and distance groups' scores (see Table 4).[43] We then repeated the analysis by examining potential for between-group differences for the course problem sets scores, exams, and overall course score (see Table 4).

Table 4. Two-Sample Mann-Whitney U and Wilcoxon Test Results for Between-Group[a] Comparisons

Item	Mann-Whitney *U*	Wilcoxon *W*	*Z*	Asymp. Sig. (2-tailed)	Exact Sig. [2*(1-tailed Sig.)]	Effect Size[c]
Quizzes 1-6	15.000	30.000	-0.417	0.677	0.755[b]	0.120
Quizzes 7-13	13.000	41.000	-0.733	0.463	0.530[b]	0.212
All Quizzes	13.000	41.000	-0.731	0.465	0.530[b]	0.211
All Problem Sets	15.000	30.000	-0.425	0.671	0.755[b]	0.123
Exams	8.000	36.000	-1.543	0.123	0.149[b]	0.445
Course	8.000	36.000	-1.543	0.123	0.149[b]	0.445

[a] Grouping Variable: Course Delivery. [b] Not corrected for ties. [c]See ref *44*.

We next wanted to see if there was a performance difference between units 1-6 and 7-13 when analyzing our students as a whole, independent of delivery course method (e.g., F2F vs.

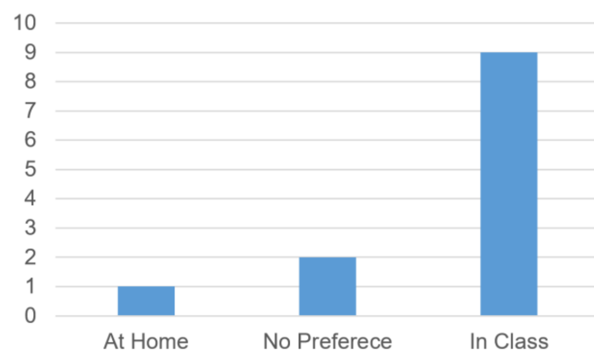
Distance). To do this, we created a composite score average for each student for the two blocks of quizzes 1 through 6 and again for quizzes 7 through 13. We then compared the composite scores using the Related Samples Wilcoxon Signed Rank Test, again maintaining nonparametric conditions for our paired-sample analysis. Our results indicated a significant difference, $p = 0.002$ ($Z = 3.059$, $r = 0.883$), for students' quiz scores from the first half of the course (quizzes 1-6), compared to their scores in the second half of the course (quizzes 7-13). Thus, the in-class quiz scores (quizzes 1-6, Medain = 4.500) were significantly higher than the take-home quiz scores (quizzes 7-13, Median = 3.708).

In considering these results, we cannot eliminate the possibility that units 7-13 were harder than 1-6, or that some students prepared less thoroughly for exams 3 or 4 (units 7-13), planning to drop one of them as their lowest midterm. It also remains unclear why F2F students underperformed (though not by a statistically significant measure) on their exams during units 7-13, relative to distance students. Perhaps, because distance students were not in the presence of the instructor, they were more obliged to form a higher level of learning autonomy and self-regulation than F2F students, which led to better results. In any case, our data did not support our original hypothesis that at-home quizzes would increase engagement and learning, to the extent that learning correlates with increased grades. We accordingly turned to qualitative feedback for a broader picture.

Student Feedback

Feedback was obtained through an anonymous, online exit survey instrument, which all twelve students completed. (See the Supporting Information for full survey results.) When asked whether they preferred quizzes at home or in class, nine students (75.0%) said "in class," one (8.33%) said "at home," and two (16.7%) said "no preference" (Figure 1).

Figure 1. Student Responses to: "Did you prefer taking the quizzes at home or in class?"



When asked to explain, the one student who preferred at-home quizzes said:

> I liked having the independence of taking the quizzes whenever I wanted before the due date. In addition, I would review the quiz pdf. and then I would look for the answer to the questions in the videos, so it did make them more engaging.

Of the nine students who said they preferred quizzes in class, only six provided additional feedback on the subject:

> There were a couple days when I was busy, and instead of finding time to watch the videos before going to class, I waited and watched them during class time. I

think that if we would have stuck with taking the quizzes in class, I would have been a little more motivated to watch the video material before going to class.

I never felt like the videos were boring, and in fact had my problem set out when watching them and would work out some of the problems while I watched. I also had a hard time remembering to take the quizzes on my own. I would have preferred to not take quizzes, especially on my own time because I have many other classes with many other assignments, and the quizzes became extremely bothersome and I feel like that served no purpose.

I didn't really feel pressured to come to class when the quizzes were online and we worked on homework independently, why not do it at home?

I like the quizzes better when they were in class. It helped me be more prepared when coming to class and motivated me to come to class.

It was easier to have the quiz in class. It was there, and one less thing to have to print off and worry about.

Tardiness and unpreparedness in some students increased. I actually got more out of videos the first half. I felt less engaged the second half because I was focused on certain aspects of the videos to do with the quiz rather than learning the whole thing in general. It became a mental block in my learning.

Our objective in giving the at-home quizzes was to see if attentiveness, engagement, and learning increased. However, student feedback generally indicated the opposite occurred. For example, from these comments we learned that one student believed the at-home quizzes removed the incentive to watch the videos before class. Another student suggested they were unnecessary for increasing engagement: “I never felt like the videos were boring [for units 1-6] . . . [I] had my problem set out when watching them and would work out some of the problems while I watched.” Another student reported that the at-home quizzes became “a mental block in my learning,” and “I felt less engaged.” Additionally, three comments reflected a perceived attendance decrease during the at-home quiz units. We accordingly calculated the attendance average for each half of the course and found that it did go down for units 7-13 (Table 5). In any event, our qualitative feedback did not support the hypothesis that at-home quizzes would increase engagement and learning.

Table 5. Class Attendance Trends Over Time

Group (Number of Students)	Average Class Attendance, %	
	Units 1–6, In-Class Quizzes	Units 7–13, At-Home Quizzes
Group 1, Face-to-Face (*N* = 7)	90.00	70.59
Group 2, Distance (*N* = 5)	84.52	56.30

CONCLUSIONS

As we considered flipping our multi-site, synchronously-broadcast organic chemistry course, we reasoned that engagement might increase if students filled out quizzes while watching lecture videos outside of class, instead of just passively viewing them and then taking their quizzes later, in class. Because engagement and learning directly correlate, we hypothesized that this structural change would increase learning and, by extension, student satisfaction. Counterintuitively, we found the opposite: students performed worse on take-home quizzes and exams (Research Question 1), and three-fourths of them expressed preference for quizzes in class (Research Question 2). Our student feedback included themes that take-home quizzes de-incentivized attendance and video-watching before class, and that they decreased engagement and learning with the videos. Thus, our results did not support our original hypothesis. Two study limitations are noted. First, our sample size is small, which is fairly common in the realm of multi-site distance teaching. Second, in-class quizzes versus take-home quizzes covered different content, which may have affected outcome as much as (or more than) the format. Nevertheless, our current observations lead us to recommend an in-class, instead of take-home, quizzing strategy when flipping college organic chemistry. This may be particularly relevant to multi-site broadcast distance educators, who face the crucial but often challenging objective of engaging distance students.[29]

DESCRIPTION OF SUPPORTING INFORMATION

Supporting materials include class schedules and syllabi, sample quiz questions, and full copies of all early-term and exit survey results for both F2F and distance students.

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REFERENCES

1. Driscoll, M. P. Cognitive Information Processing. In *Psychology of Learning for Instruction*, 2nd Edition; Allyn & Bacon: Needham Heights, MA, 1994; pp 67–110.
2. Cognitive Information Processing Theory Webpage. Expert LEARNERS. http://www.expertlearners.com/cip_theory.php (accessed Nov 2016).
3. Lauber, S. The Information Processing Model. DataWORKS Educational Research. http://dataworks-ed.com/the-information-processing-model/ (accessed Nov 2016).
4. Schunk, D. H. (1996). *Learning Theories (2nd ed.)*. Englewood Cliffs, New Jersey: Merrill, an imprint of Prentice Hall.
5. Ally, M. Foundations of Educational Theory for Online Learning. In *The Theory and Practice of Online Learning,* 2nd Edition; Anderson, T. Ed.; AU Press: Edmonton, AB, 2008; pp 21–29.
6. Ryan, M. D.; Reid, S. A. Impact of the Flipped Classroom on Student Performance and Retention: A Parallel Controlled Study in General Chemistry. *J. Chem. Educ.* **2016**, *93*, 13-23
7. Weaver, G. C.; Sturtevant, H. G. Design, Implementation, and Evaluation of a Flipped Format General Chemistry Course. *J. Chem. Educ.* **2015**, *92*, 1437-1448.

8. Hibbard, L.; Sung, S.; Wells, B. Examining the Effectiveness of a Semi-Self-Paced Flipped Learning Format in a College General Chemistry Sequence. *J. Chem. Educ.* **2015**, *93*, 24-30.
9. Christiansen, M. A. Inverted Teaching: Applying a New Pedagogy to a University Organic Chemistry Class. *J. Chem. Educ.* **2014**, *91*, 1845-1850.
10. Christiansen, M. A. Flipping Organic Chemistry in a Class that is Synchronously Taught at Multiple Geographic Sites. Presented at the Proceedings of the 2016 Biennial Conference on Chemical Education, Greeley, CO, United States, July 31–August 4, 2016.
11. Prince, M. Does Active Learning Work? A Review of the Research. *J. Engineer. Educ.* **2004**, *93*, 223-231.
12. Mazur, E. Farewell, Lecture? *Science* **2009**, *323*, 50−51.
13. Wagner, B. D. A Variation on the Use of Interactive Anonymous Quizzes in the Chemistry Classroom. *J. Chem. Educ.* **2009**, *86*, 1300−1303.
14. Crouch, C. H.; Mazur, E. Peer Instruction: Ten Years of Experience and Results. *Am. J. Phys.* **2001**, *69*, 970−977.
15. Muzyka, J. L. ConfChem Conference on Flipped Classroom: Just-in-Time Teaching in Chemistry Courses with Moodle. *J. Chem. Educ.* **2015**, *92*, 1580-1581.
16. Novak, G. M.; Gavrin, A.; Christian, W.; Patterson, E. *Just-in- Time Teaching: Blending Active Learning with Web Technology;* Prentice Hall: Upper Saddle River, NJ, 1999.
17. *Just-in-Time Teaching: Across the Disciplines, Across the Academy*, 1st ed.; Simkins, S., Maier, M. H., Eds.; New Pedagogies and Practices for Teaching in Higher Education; Stylus Publishing: Sterling, VA, 2010.
18. Brame, C. Just-in-Time Teaching (JiTT). Vanderbilt University Center for Teaching Website. https://cft.vanderbilt.edu/guides-sub-pages/just-in-time-teaching-jitt/ (accessed Nov 2016).
19. Flynn, A. B. Structure and evaluation of flipped chemistry courses: organic & spectroscopy, large and small, first to third year, English and French. *Chem. Educ. Res. Pract.* **2015**, *16*, 198-211.
20. Weaver, G. C.; Sturtevant, H. G. Design, Implementation, and Evaluation of a Flipped Format General Chemistry Course. *J. Chem. Educ.* **2015**, *92*, 1437-1448.
21. Fautch, J. M. The flipped classroom for teaching organic chemistry in small classes: is it effective? *Chem. Educ. Res. Pract.* **2015**, *16*, 179-186.
22. Jensen, J. L.; Kummer, T. A.; Godoy, P. D. d. M. Improvements from a Flipped Classroom May Simply Be the Fruits of Active Learning, *CBE – Life Sciences Education* **2015**, *14*, Article 1, 1-12.
23. Schultz, D.; Duffield, S.; Rasmussen, S. C.; Wageman, J. Effects of the Flipped Classroom Model on Student Performance for Advanced Placement High School Chemistry Students. *J. Chem. Educ.* **2014**, *91*, 1334-1339.
24. For examples, see: (a) Smith, J. D. Student attitudes toward flipping the general chemistry classroom. *Chem. Educ. Res. Pract.* **2015**, *16*, 607-614. (b) Enfield, J. Looking at the Impact of the Flipped Classroom Model of Instruction on Undergraduate Multimedia Students at CSUN. *TechTrends* **2013**, *57*, 14-27. (c) Tune, J. D.; Sturek, M.; Basile, D. P. Flipped classroom model improves graduate student performance in cardiovascular, respiratory, and renal physiology. *Adv. Physiol. Educ.* **2013**, *37*, 316-320.
25. For examples, see: (a) Fitzgerald, N.; Li, L. Using Presentation Software To Flip an Undergraduate Analytical Chemistry Course. *J. Chem. Educ.* **2015**, *92*, 1559-1563. (b) Pierce, R.; Fox, J. Vodcasts and Active-Learning Exercises in a "Flipped Classroom" Model of a Renal Pharmacotherapy Module. *Am. J. Pharm. Educ.* **2012**, *76,* Article 196, 1-5. (c) Missildine, K.; Fountain, R.; Summers, L.; Gosselin, K. Flipping the Classroom to Imrpvoe Student Performance and Satisfaction. *J. Nursing Educ*. **2013**, *52*, 597-599.
26. Bergmann, J.; Sams, A. The Flipped Classroom. In *Flip Your Classroom*; International Society for Technology in Education: Eugene, OR, 2012.

27. Fredericks, J. A.; Blumenfeld, P.; Friedel, J.; Paris, A. In *School Engagement*. Proceedings of the *Indicators of Positive Development Conference*, Washington, DC, March 11-13, 2003.
28. Marzano, R. J. *The Art and Science of Teaching: A Comprehensive Framework for Effective Instruction;* Association for Supervision and Curriculum Development: Alexandria, VA, 2007.
29. Wyatt, L. G. Nontraditional Student Engagement: Increasing Adult Student Success and Retention. *The Journal of Continuing Higher Education* **2011**, *59*, 10-20.
30. Roehl, A.; Reddy, S. L.; Shannon, G. J. The Flipped Classroom: An Opportunity to Engage Millennial Students Through Active Learning Strategies. *Journal of Family & Consumer Sciences*. **2013**, *105*, 44-49.
31. Appleton, J. J.; Christenson, S. L.; Kim, D.; Reschly, A. L. Measuring Cognitive and Psychological Engagement: Validation of the Student Engagement Instrument. *J. School Psychology*. **2006**, *44*, 427–445.
32. Libbey, H. P. Measuring Student Relationships to School: Attachment, Bonding, Connectedness, and Engagement. *Journal of School Health*. **2004**, *74*, 274-283.
33. Utah Education Network homepage. http://www.uen.org/ (accessed Nov 2016).
34. James W. Fonseca and Charles P. Bird, Under the Radar: Branch Campuses Take Off. *University Business Magazine*, October 2007. http://www.universitybusiness.com/article/under-radar-branch-campuses-take (accessed Nov 2016).
35. Kondro. W. Eleven Satellite Campuses Enter Orbit of Canadian medical education. *Can. Med. Assoc. J.* **2006**, *175*, 461-462.
36. For examples of some institutions that have domestic satellite campuses, see: (a) University of Washington, Bothell Campus Homepage. http://www.bothell.washington.edu/ (accessed Nov 2016). (b) University of Washington, Seattle Campus Homepage. http://www.washington.edu/about/ (accessed Nov 2016). (c) University of Washington, Tacoma Campus Homepage. http://www.tacoma.uw.edu/ (accessed Nov 2016). (d) Texas Tech University System: Campuses & Academic Sites Homepage. http://www.texastech.edu/campuses.php (accessed Nov 2016). (e) University of Illinois Campuses Homepage. https://www.uillinois.edu/campuses/ (accessed Nov 2016). (f) Penn State Campuses Homepage. http://www.psu.edu/academics/campuses (accessed Nov 2016). (g) University System of Maryland Homepage. http://www.usmd.edu/institutions/ (accessed Nov 2016). (h) Utah State University Regional Campuses and Distance Education Homepage. https://regionalcampuses.usu.edu/locations/ (accessed Nov 2016). (h) University of North Carolina, "Our 17 Campuses" Homepage. http://www.northcarolina.edu/?q=content/our-17-campuses (accessed Nov 2016).
37. McLaughlin, J. E.; Griffin, L. M.; Esserman, D. A.; Davidson, C. A.; Glatt, D. M.; Roth, M. T. Gharkholonarehe, N.; Mumper, R. J. Pharmacy Student Engagement, Performance, and Perception in a Flipped Satellite Classroom. *Am. J. Pharm. Educ.* **2013**, *77* (9), 196; DOI:10.5688/ajpe779196.
38. Christiansen, M. Flip Teaching College Chemistry in Broadcast Classrooms. In *Interdisciplinary Approaches to Distance Teaching: Connecting Classrooms in Theory and Practice;* Blackstock, A., Straight, N., Eds.; Routledge: New York, **2015**; pp 65–86.
39. For 11 different cross-disciplinary examples of class sizes and approaches in IVC teaching, see: *Interdisciplinary Approaches to Distance Teaching: Connecting Classrooms in Theory and Practice;* Blackstock, A., Straight, N., Eds.; Routledge: New York, **2015**; pp 65–86.
40. Videos are available online at: Mike Christiansen Organic Chemistry YouTube Homepage. https://www.youtube.com/playlist?list=PLBwHfJmqJz5hlnrx6HdYEuVYmSyFLxP-m (accessed Nov 2016).
41. Canvas Homepage. https://www.canvaslms.com/ (accessed Nov 2016).
42. For sample problem set questions, see the Supporting Information of reference 9.

43. Razali, N. M.; Wah, Y. B. Power Comparisons of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling Tests. *Journal of Statistical Modeling and Analytics* [Online] **2011**, *2*, 21-33. https://www.researchgate.net/publication/267205556_Power_Comparisons_of_Shapiro-Wilk_Kolmogorov-Smirnov_Lilliefors_and_Anderson-Darling_Tests (accessed Nov 2016).
44. Pallant, J. *SPSS Survival Manual: A Step by Step Guide to Data Analysis using SPSS,* 4th edition; Open University Press: Crows Nest NSW, Australia, 2011.