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Michael A. Christiansen
Utah State University

Louis Nadelson
Colorado Mesa University

Lianna K. Etchberger
Utah State University

Marilyn M. Cuch
Utah State University

Trish A. Kingsford
Utah State University

Leslie O. Woodward
Utah State University

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By Michael A. Christiansen,[a,*] Louis Nadelson,[b] Lianna Etchberger,[a] Marilyn Cuch,[a] Trish A. Kingsford,[a] and Leslie O. Woodward[a]

[a] Utah State University, Uintah Basin Regional Campus: 320 North Aggie Blvd, Vernal, UT, 84078, U.S.A. Fax: (435)-789-3916

[b] Colorado Mesa University, College of Computer Science, Mathematics and Statistics, 1100 North St, Grand Junction, CO 81501

* Phone: (435)-722-1761; email: m.christiansen@usu.edu

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ABSTRACT

In synchronously-delivered, multi-site classrooms, the physical separation between distance students and instructors may create a perceived divide that negatively affects learning. Building on prior experience in flipping organic chemistry in single-site face-to-face (F2F) classes, we decided to extend our approach to multi-site, synchronously-delivered *general* chemistry courses. Our thought was to narrow the perceived instructor-student divide in distance teaching by using the flexible in-class time that flipping affords to increase the number of positive teacher/distance-student interactions. In this effort, we gradually developed a technique called "bridging questions," through which the instructor becomes more familiar with student interests and then connects those interests to chemistry topics discussed in class. Despite anticipating overall positive results, actual consequences were mixed: after flipping the class, evaluation scores and positive feedback increased slightly. However, the mean final exam scores *decreased* for F2F students by 26.2%, but increased for distance students by 4.4% (not statistically significant). Thus, this new approach (flipping with bridging questions) may have unintentionally skewed our focus to distance students, though this conclusion is speculative. (We acknowledge statistical limitations, due to small sample sizes.) We accordingly advocate proactive efforts to balance engagement between both F2F and distance sites. In this paper we also discuss modifications we made to adapt our flipped format to multi-site, synchronously-delivered freshman chemistry courses, as well as the basic idea of bridging questions in general.

BACKGROUND

Many North American universities have expanded rural students' access to higher education by building satellite campuses.[1,2] Utah State University (USU) now has 32 campuses or learning centers across Utah, from which geographically-dispersed faculty deliver a diverse portfolio of distance courses.[3] These are often "broadcast"-taught through Interactive Video-Conferencing (IVC) technology.[4] This allows professors to synchronously teach both face-to-face (F2F) and distance students at multiple sites, sometimes hundreds of miles apart, in real time. Thus, many traditional USU degrees that were once inaccessible to place-bound students[5] in rural Utah can now be earned through curricula delivered via coordinated networks of geographically-dispersed main- and satellite-campus faculty.

Despite its advantages for rural students, broadcast teaching presents unique challenges. Because distance learners watch professors on-screen from miles away, but rarely interact in-person, they sometimes feel disconnected from their instructors and fellow students at other sites.[6-7] As IVC professors are not physically present, distance students who are not regularly engaged in class sometimes get bored, have off-topic discussions with peers, leave early or arrive late, or skip class.[8] Furthermore, because professors can only hear distance sites when students activate their microphones, it becomes difficult to ensure on-task behavior by distance students. (Distance sites usually have an on-site tech facilitator, but no faculty or peer instructor). In effect, the inherent student-teacher divide in IVC settings can amplify the key dilemma articulated by *transactional distance theory:* when students feel detached from their instructors and peers, they engage less; and when they engage less, learning and retention decrease.[9-11] Although *students* are ultimately responsible for their own behavior, the pedagogies employed in multi-site IVC teaching can make a difference in engagement levels and learning experiences.

By fall of 2014, we had flipped organic chemistry for two years, but only in fully-F2F classes.[12] (For a thorough review of flipped learning –beyond the scope of this communication—please see the sources in ref 13.) We had also separately taught IVC *general* chemistry for two years using a traditional-lecture (TL) format. Enthused by the positive results of flipping, but aware of the potential difficulty of adapting it to IVC settings, we looked to the literature and found only one peer-reviewed paper on the subject.[9] In it, McLaughlin reported inverting a pharmaceutics course that was synchronously delivered to one F2F and two distance sites.[9] Though grades did not change significantly relative to TL, survey data showed that most students preferred flipping and claimed it "significantly enhanced" their learning, as well as "the quality and efficiency of interactions in the . . . satellite classroom".[9] Recognizing the literature gap in IVC *chemistry* education, we began working to fully flip our two-semester general chemistry IVC course.[14] In this paper, we disclose our approach to some of the ensuing challenges, which required adapting our previous design.[12] Thus, our aim here is to help fill the literature void and provide a starting point for educators to flip multi-site IVC classes. This study was preapproved by an Institutional Review Board (IRB).

POPULATIONS STUDIED

Through the public *Utah Education Network* (UEN),[15] in-class instruction was synchronously delivered from our origination site (USU Uintah Basin Campus) to a combination of F2F and distance locations. Table 1 shows each semester's number of students, chemistry majors, distance sites, and gender breakdowns. Our small class sizes, though atypical for most institutions, are common to rural satellite-campus settings.[9,16]

Table 1. Number of Students, Chem Majors, Distance Sites, and Gender Breakdowns for Each Semester

General Chemistry I							
Courses (TL is Traditional Lecture)	Number of Students		Chem Majors		Mean GPA		Distance Sites
	F2F (male:female)	Distance (male:female)	F2F	Distance	F2F	Distance	
Fall 2012 (TL)	14:4	14:4	3	0	3.41	3.03	3
Fall 2013 (TL)	4:6	9:2	1	1	3.30	3.27	2
Fall 2014 (Flipped)	3:3	14:4	0	2	3.09	2.81	3
Fall 2015 (Flipped)	8:2	22:13	0	1	2.90	3.29	1
General Chemistry II							

Courses (TL is Traditional Lecture)	Number of Students		Chem Majors		Mean GPA		Distance Sites
	F2F (male:female)	Distance (male:female)	F2F	Distance	F2F	Distance	
Spr 2013 (TL)	9:2	7:3	2	0	3.44	3.04	2
Spr 2014 (TL)	4:3	3:1	1	1	3.35	2.83	1
Spr 2015 (Flipped)	3:3	3:4	1	1	3.37	3.36	2
Spr 2016 (Flipped)	3:2	9:6	0	2	3.40	3.20	4

FLIPPED COURSE STRUCTURE

We spent a year making 252 content videos of narrated PowerPoint slides with picture-in-picture capture of the instructor, or footage of the instructor working problems on a board.[17] Table 2 shows videos-per-course, videos-per-chapter, and average lengths.

Table 2. Video Quantities and Lengths for Our Two General Chemistry Courses

Video Descriptors	General Chemistry I	General Chemistry II
Total Chapters Covered	12	12
Total Videos	99	143
Mean Videos per Chapter	8.3	12
Mean Video Length (min)	7:31	6:30

Each 14-week course included two 100-minute weekly classes, covering about one textbook chapter per week. Before class, students watched four to six videos (~30 to 39 total minutes), according to our syllabus (available in the Supporting Information). To incentivize attendance and video-watching, each week began with a quiz about the videos. For the rest of class, students worked in assigned groups of two to four people on problem sets (~20 questions per set, available in the Supporting Information), which included mixed-format questions (open-answer, multiple-choice, etc.) written by the instructor or adapted from our text's question databank. In total, students had 12 quizzes (~9% of their grade, lowest score dropped) and 12 problem sets (~18% of their grade, lowest score dropped). They also took five exams (four midterms and a comprehensive final, lowest midterm dropped), worth ~67% of their grade, and a formative entrance exam, worth ~6% of their grade. Students handed in one problem set per group and all received the same score. However, at the semester's end, we used multipliers derived from anonymous "peer grades" to adjust *individual* problem set grades, according to eq 1.[12] This helped encourage attendance, preparation, and contribution to group work.

Individual Problem Set Grade = (Group's Collective Problem Set Grade) × Y

In Equation 1, Y is the average of peer grades from all group members, calculated by converting our institution's letter-grade percent values to numbers, as follows: F = 0.5, D^- = 0.575, D = 0.65, D^+ = 0.6833, C^- = 0.7167, C = 0.75, C^+ = 0.7833, B^- = 0.8166, B = 0.85, B^+ = 0.8833, A^- = 0.9167, A = 1.

In our prior flipped organic courses, we anecdotally observed that if group assignment was optional, then students usually chose to work alone, and attendance and grades declined. We accordingly *required* group work, except in cases of extreme intergroup conflict, for which students could privately request a change from the instructor, or of distance students who were alone at their individual sites. Such "lone-wolf" students were rare (three out of 128), but for them only, we made working in a cross-site group *optional* (via video-chat software). All chose to work alone. To mitigate possible disadvantages of lacking a group, the instructor regularly checked in with them over the broadcast system. (The same was done for *all* distance students; the only difference was that these "lone-wolves" were addressed individually, instead of as groups.) In the end, these students' mean grades were statistically identical to the overall course averages. Thus, any extra attention they received from the instructor may have balanced the detriment of lacking a group. Additionally, each mini-lecture the instructor gave was delivered to all students at all sites, so as to not unfairly favor any group or individual over another.

In class, the instructor intermittently observed student work in-person for F2F students, or –for distance students—by checking in with them over the microphone every five to seven minutes. As questions arose, the instructor directed students to resources or gave mini just-in-time-teaching (JiTT) lectures[13e,18] to clarify. Students submitted weekly problem sets any time up to the due date and got feedback without grade punishment. Distance students did this through email or scanned or smartphone-captured images of their work. When done during class, the instructor gave feedback immediately using an overhead document camera, or made annotations to students' submissions and replied by email, either problem-by-problem or across an entire problem set. Thus, the extra class time freed up by flipping was leveraged for Peer Instruction (students teaching each other in groups),[13e,19] problem-based learning,[20] prompt feedback, and JiTT mini-lectures.[13e,18]

BRIDGING QUESTIONS

Regardless of pedagogy, the perceived divide between teachers and distance students in multi-site IVC courses is a significant concern.[9-11] We sought to leverage the class flexibility provided by flipping to narrow this distance. The unconventional method we developed was to intermittently ask questions, called "bridging questions," in rotation from every student (both F2F and distance) during class.[13a] To explain, during mini-lectures in class, the instructor alternatingly inserted seemingly random questions to individuals about their jobs, interests, favorite movies, feelings about the current topic, and so forth, and then worked their responses into mini-lectures. For instance, what follows is an actual paraphrased dialog (names changed) from one of our class sessions:

> *Instructor* (interrupting his own mini-lecture on chemical solubility): "Brittney at our Moab site, could you please tell me the name of your favorite breakfast cereal?"
>
> *Brittney:* "Captain Crunch."
>
> *Instructor:* "Brittney, what is so different about Captain Crunch, relative to many other cereals?"
>
> *Brittney:* "It stays crunchy for longer."
>
> *Instructor:* "Exactly! That is because this particular cereal is not as soluble in milk as a lot of others. Ionic compounds are very much like this. To see this, let's take a look at our solubility rules . . ."

Conceptually, this unorthodox approach helps connect the instructor to students and students to each other across sites, which theoretically engages and draws them in. However, we had to develop some rules:

- Questions should not be invasive or overly personal.

- Recognize that most responses will not seamlessly dovetail into the current topic. However, students find it funny and engaging when the instructor humorously or awkwardly shoehorns seemingly un-relatable subjects into the present discussion. Thus, the teacher must stay lighthearted and adaptable.
- Through anonymous surveys, we found that students dislike being asked tough questions in class individually, because not knowing the answer can cause embarrassment. Thus, *we pose content questions to groups*, but *personal questions to individuals*.
- Like any technique, bridging questions should only be used when appropriate and not awkwardly forced just to meet a quota.

We have anecdotally seen that bridging questions are only needed for the first three to five weeks of class. If responses are recorded, then the instructor can insert student interests into mini-lectures in rotation thereafter, without asking new bridging questions, or gradually attenuate interest insertion, once a rapport is developed. Additionally, the instructor can embed student interests into *content* questions, which can scaffold up during mini-lectures. We have also used this approach in TL classes, though not as much, due to time restrictions imposed by needing to deliver content.

Though people and teachers have used such techniques for centuries to forge interpersonal connections, this is first communication we know of to specifically apply it the transactional distance gap in IVC classrooms. Again, our use of bridging questions is only possible because of the class time flexibility proffered by flipped learning.

RESULTS AND DISCUSSION

We have seen a positive change in our classroom dynamic since we first began using bridging questions. In effect, bridging questions make every semester different, custom-tailored to the interests of each class, which draws both F2F and distance students into our discussions like never before. Examples have included:

- Likening basketball to molecular orbital theory for a student who previously played on a junior college team.
- Discussing the combustion of fossil fuels in military vehicles with a student who was an army mechanic.
- Connecting water purification chemistry to the recent lead contamination of drinking water in Flint, Michigan with a student who moved to Utah from Michigan.
- Talking about the chemistry of pesticides and fertilizers with a student who lived on a farm.

In these examples, we connected current class topics to students' personal lives. Again, we would never have *known* about students' interests if not for bridging questions; and our ability to use them would be limited without the time flexibility created by flipped learning. Surprisingly, we saw a slight statistical grade drop on our comprehensive ACS normalized year-end final during the flipped years, though only for F2F students; analogous distance scores *increased*, but not by a statistically significant amount (Figure 1). We also observed an upward trend, also not statistically significant, in our IDEA[21] course evaluation scores (see Figure 2 trend-line), calculated from compiled student responses to a long list of comprehensive course survey questions. Thus, it seems that F2F students in the flipped courses performed worse ($F(1,26) = 9.37$, $p<.01$), and distance students the same, though qualitative data (IDEA summary evaluation scores) may indicate that flipping is slightly *preferred*. Unfortunately, the IDEA instrument (Figure 2 data) does not report F2F and distance results separately, so we are unable to parse the two. Furthermore, our small class sizes also limit our ability to generalize to other conditions (e.g., large-scale courses), and they increase the skewing effect of outliers. (For full analysis, see the Supporting Information.)

In considering their improved performance during the flipped years (Figure 1), one might ask if the distance students were better prepared academically than their F2F counterparts. If mean GPA's are an indicator, then the answer is no, as our distance students' were very similar or slightly lower than their F2F counterparts' (see Table 1).

Figure 1. Mean percentiles on normalized final exam (GEN-CHEM II): face-to-face (F2F) vs. distance

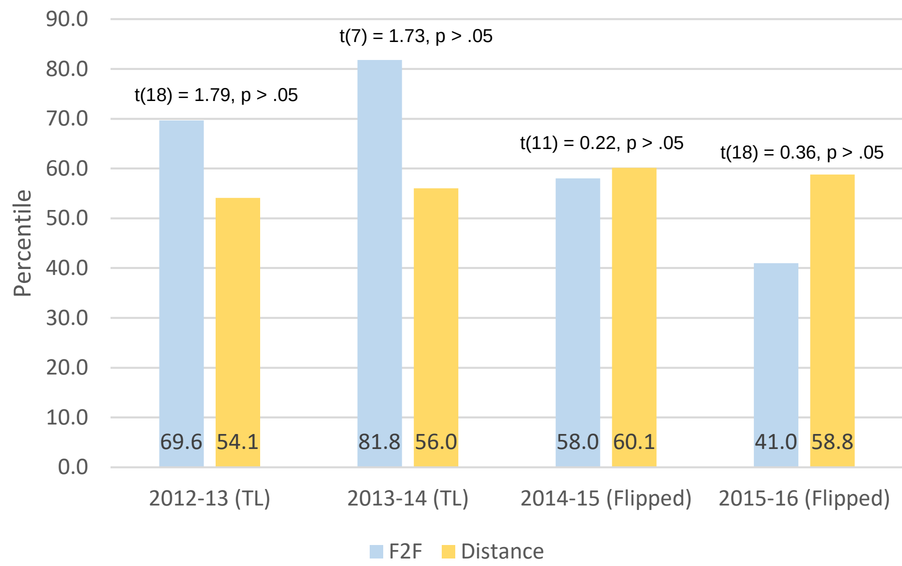
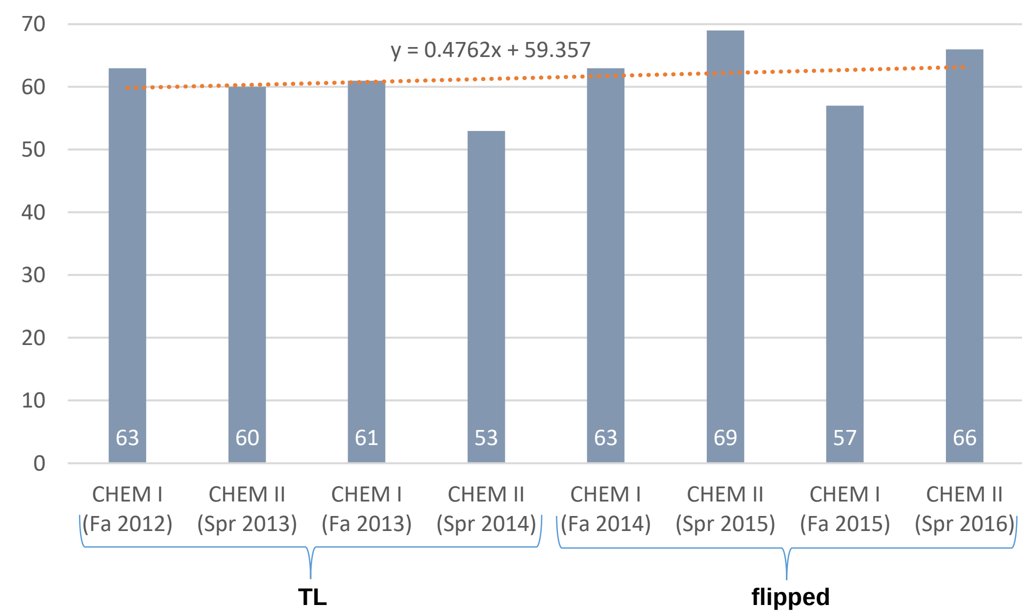


Figure 2. GEN-CHEM I/II adjusted IDEA[21] "Summary Evaluation" scores. Scores of 63+ fall in the top 10% (90th percentile) of all disciplines at all IDEA universities. Scores of 56-62 fall in the top 20-30% (70th percentile) range.



CONCLUSIONS

Studies affirm that in synchronously-delivered, multi-site classrooms, the geographic distance between IVC students and instructors may negatively affect learning.[6-8] We sought to narrow this perceived gap[9-11] by using the greater in-class time flexibility proffered by flipped learning[13] to increase the number of positive interactions between the teacher and distance students. We accordingly developed a technique called “bridging questions” to become more familiar with student interests and then embed those into in-class mini-lectures. Though we anticipated positive consequences, we observed mixed results: after flipping the class, evaluation scores and positive feedback increased. However, mean final exam scores decreased for F2F students, but not for distance students, whose performance trended toward improvement. Thus, our bridging-question approach may have unintentionally skewed focus to distance students. However, this is speculative because there was no feedback from F2F students to indicate that they felt overlooked. Nevertheless, for those interested in implementing similar methods, we suggest making a conscious effort to engage both F2F and distance students equitably.

ASSOCIATED CONTENT

The Supporting Information file includes a breakdown of student majors for all participants; sample course schedules and syllabi; sample video quiz and problem set questions; full course evaluation data; and complete statistical analysis of our students’ exam performance.

REFERENCES

1. For examples, see: (a) University of Washington, Bothell Campus Homepage. http://www.bothell.washington.edu/ (accessed Feb 2017). (b) University of Washington, Seattle Campus Homepage. http://www.washington.edu/about/ (accessed Feb 2017). (c) University of Washington, Tacoma Campus Homepage. http://www.tacoma.uw.edu/ (accessed Feb 2017). (d) Texas Tech University System: Campuses & Academic Sites Homepage. http://www.texastech.edu/campuses.php (accessed Feb 2017). (e) University of Illinois Campuses Homepage. https://www.uillinois.edu/campuses/ (accessed Feb 2017). (f) Penn State Campuses Homepage. http://www.psu.edu/academics/campuses (accessed Feb 2017). (g) University System of Maryland Homepage. http://www.usmd.edu/institutions/ (accessed Feb 2017). (h) Utah State University Regional Campuses and Distance Education Homepage. http://distance.usu.edu/ (accessed Feb 2017). (i) University of North Carolina, “Our 17 Campuses” Homepage. http://www.northcarolina.edu/?q=content/our-17-campuses (accessed Feb 2017). (j) Kondro. W. Eleven Satellite Campuses Enter Orbit of Canadian medical education. *Can. Med. Assoc. J.* **2006**, *175*, 461-462.
2. 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 Feb 2017).
3. “Locations.” USU distance education website. https://regionalcampuses.usu.edu/locations/ (accessed Feb 2017).
4. (a) Bertscha, T. F.; Callasb, P. W.; Rubina, A.; Caputoc, M. P. Riccid, M. A. APPLIED RESEARCH: Effectiveness of Lectures Attended via Interactive Video Conferencing Versus In-Person in Preparing Third-Year Internal Medicine Clerkship Students for Clinical Practice Examinations (CPX). *Teach. Learn. Med. Int. J.* **2007**, *19*, 4-8. (b) Radford, A. W. Learning at

a Distance: Undergraduate Enrollment in Distance Education Courses and Degree Programs. U.S. Dept. Educ.: Washington, DC; October 2011. (c) Congdon, H. B.; Nutter, D. A.; Charneski, L.; Butko, P. Impact of Hybrid Delivery of Education on Student Academic Performance and the Student Experience. *Am. J. Pharm. Educ.* **2009**, *73*, Article 121. (d) Moridani, M. Asynchronous Video Streaming vs. Synchronous Videoconferencing for Teaching a Pharmacogenetic Pharmacotherapy Course. *Am. J. Pharm. Educ.* **2007**, *71*, Article 16. (e) Robertson, J. L.; Shrewsbury, R. P. Video Teleconferencing in the Compounding Laboratory Component of a Dual-Campus Doctor of Pharmacy Program. *Am. J. Pharm. Educ.* **2011**, *75*, Article 181. (f) MacLaughlin, E. J.; Supernaw, R. B.; Howard, K. A. Impact of Distance Learning Using Videoconferencing Technology on Student Performance. *Am. J. Pharm. Educ.* **2004**, *68*, Article 58.

5. Hoyt, J. Howell, S. Why Students Choose the Branch Campus of a Large University. *The Journal of Continuing Higher Education,* **2012**, *60*, 110-116.
6. (a) Larreamendy-Joerns, J.; Leinhardt, G. Going the Distance with Online Education. *Rev. Educ. Res.* **2006**, *76* (4), 567-605. (b) Vrasidas, C.; McIsaac, M. S. Factors influencing interaction in an online course. *Am. J. Distance Educ.* **1999**, *13* (3), 22-36.
7. (a) Lee, H.J.; Rha, I. Influence of structure and interaction on student achievement and satisfaction in web-based distance learning. *Educ. Technol. Soc.* **2009**, *12* (4), 372-382. (b) Alshari, N.Z.; Galt, K. A. Evaluation of an instructional model to teach clinically relevant medicinal chemistry in a campus and a distance pathway. *Am. J. Pharm. Educ*. **2008**, *72* (2), Article 31. (c) Henriksen, B.; Roche V. Creation of medicinal chemistry learning communities through enhanced technology and interdisciplinary collaboration. *Am. J. Pharm. Educ.* **2012**, *76* (8), Article 158. (d) Mehvar, R. A participation requirement to engage students in a pharmacokinetics course synchronously taught at a local and distant campus. *Am. J. Pharm. Educ.* **2010**, *74* (7), Article 118. (e) Steinberg, M.; Morin, A. K. Academic performance in a pharmacotherapeutics course sequence taught synchronously on two campuses using distance education technology. *Am. J. Pharm. Educ.* **2011**, *75* (8), Article 150.
8. Sweeten, T. L. Interactive Videoconferencing versus the Face-to-Face Biology Classroom: Understanding Student Attitudes and Behavior. In *Interdisciplinary Approaches to Distance Teaching: Connecting Classrooms in Theory and Practice;* Blackstock, A., Straight, N., Eds.; Routledge: New York, **2015**; pp 39–51.
9. 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*, Article 196.
10. Stein, D.S.; Wanstreet, C.E.; Calvin J.; Overtoom, C.; Wheaton J.E. Bridging the transactional distance gap in online learning environments. *Am. J. Distance Educ.* **2005**, *19*(2), 105-118.
11. Lear, J. L.; Ansorge, C.; Steckelberg, A. Interactivity/community process model for the online education environment. *J. Online Learn. Teach*. **2010**, *6*, 71-77.
12. Christiansen, M. A. Inverted Teaching: Applying a New Pedagogy to a University Organic Chemistry Class. *J. Chem. Educ.* **2014**, *91*, 1845-1850.
13. (a) Bergmann, J.; Sams, A. The Flipped Classroom. In *Flip Your Classroom*; International Society for Technology in Education: Eugene, OR, 2012. (b) 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. (c) Weaver, G. C.; Sturtevant, H. G. Design, Implementation, and Evaluation of a Flipped Format General Chemistry Course. *J. Chem. Educ.* **2015**, *92*, 1437-1448. (d) 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. (e) Muzyka, J. L. ConfChem Conference on Flipped Classroom: Just-in-Time Teaching in Chemistry Courses with Moodle. *J. Chem. Educ.* **2015**, *92*, 1580-1581. (f) 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. (g) Weaver, G. C.; Sturtevant, H. G. Design, Implementation, and Evaluation of a Flipped Format General Chemistry Course. *J. Chem. Educ.* **2015**, *92*, 1437-1448. (h) Fautch, J. M. The flipped classroom for teaching organic chemistry in small classes: is it effective? *Chem. Educ. Res. Pract.* **2015**, *16*, 179-186. (i) 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. (j) 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. (k) Smith, J. D. Student attitudes toward flipping the general chemistry classroom. *Chem. Educ. Res. Pract.* **2015**, *16*, 607-614. (l) Enfield, J. Looking at the Impact of the Flipped Classroom Model of Instruction on Undergraduate Multimedia Students at CSUN. *TechTrends* **2013**, *57*, 14-27. (m) 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. (n) Fitzgerald, N.; Li, L. Using Presentation Software to Flip an Undergraduate Analytical Chemistry Course. *J. Chem. Educ.* **2015**, *92*, 1559-1563. (o) 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. (p) Missildine, K.; Fountain, R.; Summers, L.; Gosselin, K. Flipping the Classroom to Improve Student Performance and Satisfaction. *J. Nursing Educ*. **2013**, *52*, 597-599.

14. For preliminary findings, see: 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.
15. Utah Education Network homepage. http://www.uen.org/ (accessed Feb 2017).
16. *Interdisciplinary Approaches to Distance Teaching: Connecting Classrooms in Theory and Practice;* Blackstock, A., Straight, N., Eds.; Routledge: New York, 2015.
17. Videos are available online at: Mike Christiansen General Chemistry YouTube Homepage. https://www.youtube.com/playlist?list=PLBwHfJmqJz5h5a6UxWpMrxV-jSlMKNSIn (accessed Feb 2017).
18. (a) 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. (b) *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. (c) Christiansen, M. A.; Lambert, A. M.; Nadelson, L. S.; Dupree, K. M.; Kingsford, T. A. In-Class Versus At-Home Quizzes: Which is Better? A Flipped Learning Study in a Two-Site Synchronously Broadcast Organic Chemistry Course. *J. Chem. Educ.* **2016**, *94*, 157-163.
19. (a) Mazur, E. Farewell, Lecture? *Science* **2009**, *323*, 50−51. (b) Wagner, B. D. A Variation on the Use of Interactive Anonymous Quizzes in the Chemistry Classroom. *J. Chem. Educ.* **2009**, *86*, 1300−1303. (c) Crouch, C. H.; Mazur, E. Peer Instruction: Ten Years of Experience and Results. *Am. J. Phys.* **2001**, *69*, 970−977.
20. Prince, M. Does Active Learning Work? A Review of the Research. *J. Engineer. Educ.* **2004**, *93*, 223-231.
21. IDEA (Individual Development and Educational Assessment) homepage. http://ideaedu.org/ (accessed Feb 2017).

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