JOURNAL OF CHEMICAL EDUCATION

Article

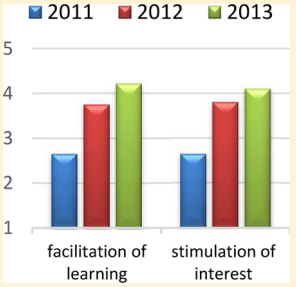
pubs.acs.org/jchemeduc

Student Response to a Partial Inversion of an Organic Chemistry Course for Non-Chemistry Majors

Kathleen S. Rein*,† and David T. Brookes‡

†Department of Chemistry and Biochemistry and ‡Department of Physics, Florida International University, Miami, Florida 33199, United States

ABSTRACT: We report the student response to a two-year transformation of a one-semester organic chemistry course for nonchemistry majors. The transformed course adopted a peer led team learning approach and incorporated case studies. Student attitudes toward the course transformation were assessed throughout the semester, and adjustments to the methods were made in response to student surveys. No change in student performance on exams was observed compared to a traditional lecture course. However, significant improvements in the end of course "Student Assessment of Instruction" were recorded.



KEYWORDS: *Second-Year Undergraduate, Upper-Division Undergraduate, Organic Chemistry, Inquiry-Based/Discovery Learning, Student-Centered Learning*

INTRODUCTION AND OBJECTIVES

Teaching chemistry to nonchemistry majors can present unique challenges for faculty. This is particularly true when the subject is as infamous as organic chemistry. Students begin the semester with preconceived notions about the difficulty of the material and are intimidated by what they have heard from their peers[1] or in the popular media. Recall Skylar's comments to Will regarding organic chemistry in the film *Good Will Hunting*:

> *"Yeah, it's SO much fun studying organic chemistry. Are you mad? Have you completely lost your mind? Nobody studies it for fun."*[2]

Instructors have much to overcome from day one. Often students resent the need to meet this requirement: an attitude that can be exacerbated by the abstract nature of the subject and the student's inability to perceive either the relevance that organic chemistry has to their major or any connections to everyday life. Attendance and student engagement in these required courses for nonmajors is often low. Student-centered, guided-inquiry instruction methods such as PBL (problem-based learning), POGIL (process-oriented guided-inquiry learning) or PLTL (peer led team learning) have been reported to enhance student performance, engagement, and satisfaction in science courses.[3,4] The majority of these studies have focused on courses for science majors. The few reports related to teaching science to nonmajors have indicated that student-centered, inquiry-based approaches are effective in improving attitudes and performance among nonmajors as well.[5,6]

One of the primary challenges of transforming any course into a more student-centered format lies in the fear of change, both on the part of the students and the instructor. First, it is well documented that students are resistant to change.[7] This resistance can lead to declining course evaluations and general dissatisfaction with the course.[8] Second, instructors also struggle with change, which often means letting go of their own preconceptions about learning based on their prior learning experiences.[9] These two factors can compound together. Faced with student dissatisfaction, instructors may quickly give up on innovation and retreat to the more comfortable and familiar "lecture mode" of instruction.

We report the student response to a two-year course transformation of a one-semester organic chemistry course for dietetics and nutrition and environmental studies majors. Ultimately, the goal of the course transformation was to increase learning, retention, and student satisfaction when compared to a traditional lecture format. The approach taken was to increase student engagement through the use of active learning pedagogies and to stimulate student interest in the course material through the use of case studies. One of the key elements of the course transformation was the instructor's repeated use of surveys of her students' opinions as a formative assessment tool[10] to gauge their reactions to the new course elements and to make necessary adjustments in light of those opinions. Our research goals were to (a) evaluate the effectiveness of the transformation and (b) determine if adjustments made in response to evaluative surveys could improve students' attitudes toward the transformation.

Methodology and Course Transformation

The transformed course was approximately 50% inverted and most closely resembled a PLTL-based approach to instruction as the learning activities did not replace but rather supplemented the lecture.[11] The inverted classroom involves reversing the timing of content delivery (typically the lecture part of a traditional classroom) and homework.[12] Therefore, the students participate in a passive way by viewing content

DOI: 10.1021/ed500537b
J. Chem. Educ. XXXX, XXX, XXX−XXX

outside of the classroom, which frees class time for active learning in the classroom. Technological advances have made content delivery through videos, recorded lectures, or podcasts accessible to even the least tech savvy of us.[13,14] In a typical week, students met for small group (5−6 students) problem solving "workshops" during one of two scheduled class periods and for a lecture during the second. Incorporation of exam days into this schedule resulted in 12 workshops during the 16-week semester. Undergraduate learning assistants (LAs) acted as peer leaders on workshop days, which resulted in an instructor/student ratio between 1:15 and 1:18. To offset the class time devoted to workshops, students were required to view prerecorded videos. PowerPoint presentations, which had been used in the traditional lecture course, were converted to narrated videos using the software Camtasia and were uploaded to YouTube. Some of the videos were prepared using the free program SmoothDraw along with Camtasia. The majority of the videos are "unlisted", meaning that they cannot be identified through a search and can only be accessed through the URL. Students accessed the videos via links in the course learning management system (LMS). Videos ranged in length from 5 min to a maximum of 15 min with an average time of 11 min. Weekly video assignments ranged in time from 1.25 h to as little as 37 min. A total of 10 h of videos was recorded. Because many of the problems presented during workshops had been used as examples during the traditional lecture-only course, it was not necessary to compensate for all of the time devoted to workshops.

In 2012, each group was given a case study assignment approximately two-thirds through the semester. Teaching with case studies has been used widely in law, medicine, and business[15] but less frequently in science teaching. Typically, the objective of the case-study approach is skill-building. In our case, the objective was to help students make connections between organic chemistry and "real life". The timing of the case presentations was such that they were used to reinforce or illustrate earlier concepts rather than to introduce new concepts. Each group was required to prepare a PowerPoint presentation detailing the organic chemistry concepts underlying the issue and present their findings to the class in a 10-min talk during the last week of the regular class period. These presentations were worth 10% of their overall grade. Examples of case-study topics and the corresponding concepts are listed in Table 1. When taught in 2013, the case studies were incorporated into the lecture period and were presented either by the LAs or by the professor in the form of whole-class discussion. Bonus questions related to case studies were included on exams and could raise a student's overall grade by 2%.

Students were surveyed periodically throughout the course: immediately after the first and second workshops, immediately after the first exam, and after the final exam. Surveys were conducted online through a MOODLE (modular object-oriented dynamic learning environment) platform. Students who answered the surveys did receive one extra-credit point per answer, which could contribute up to 1.5% of their overall course grade. After the final exam, students were given an opportunity to explain their answers to their survey questions and to make any open-ended comments on the course. Finally, the results of the institution's end-of-course faculty evaluation are provided as a measure of student satisfaction.

Table 1. Case-Study Topics and Relevant Concepts

Case-Study Topic	Relevant Concepts
Thalidomide and chiral drugs	stereochemistry
Barry Bonds designer steroids	synthesis, structure elucidation
Fix-a-Flat	cationic polymerization
Shellac manicure	free-radical polymerization
Melamine cyanurate in pet food	aromaticity, pK_a, hydrogen bonding
Curcumin in turmeric[a]	keto−enol tautomerization, pK_a, UV−vis spectroscopy
Taxol synthesis	synthesis of complex molecules
DHA and EPA in baby formula	PUFAs structure, chemical, and biological properties
Disposable diapers and contact lenses	cationic polymerization and intermolecular interactions
Postit note glue vs superglue adhesives	anionic/cationic polymerization and intermolecular interactions

[a]Adapted from the National Center for Case-Study Teaching.[16]

RESULTS

This course transformation appeared to have little effect on the overall grades or completion rate. The average of three exams among students who completed the course was 62.7% (SD = 16.8, n = 225) in 2012 and 64.2% (SD = 14.5, n = 192) in 2013 compared to 63.5% (SD = 14.2, n = 222) for the traditional lecture course taught in 2011. A two-tailed t-test confirms that there is no significance difference in final grades between the years 2011 and 2012 (t = 0.55, p = 0.29) or years 2011 and 2013 (t = 0.13, p = 0.45). While the exams were not identical from year to year, questions were written based on the same learning objectives, and all exams had the same point distribution of multiple choice, short answer, and extended response questions. In some instances, minor changes to wording or molecules were changed. The percentage of students who completed all three exams was 88% during the two semesters that the transformed class was taught compared to 90% (n = 80) for the traditional class (n = 155), (χ^2 = 0.97, p = 0.32). After each of the first two workshops, the majority of the students reported that group problem solving helped them to learn the material and that watching the course videos prepared them for problem solving (Figure 1). After the first exam, the majority of students felt that problem solving was an effective or somewhat effective way to prepare for exams (Figure 1). There are no statistical difference in student responses (χ^2 < 2.5, p > 0.12) to early and midcourse surveys between weeks within the same year or between the same weeks of different years, with a single exception. After week one, 78% (n = 59) of respondents indicated that watching course videos prepared them for workshops in 2012 versus 56% (n = 84) of respondents in 2013 (χ^2 = 5.24, p = 0.02). Students appeared to be less satisfied with videos during the first week of 2013. We do not have an explanation for this observation. However, there is no statistical difference in the combined responses of "yes" and "somewhat" when compared to all other possible responses (p = 1, two-tailed Fisher exact probability), and by the end of week two, students were equally satisfied with watching videos during both years (χ^2 = 0.04, p = 0.84).

End of Course Surveys

The results of the end of course survey are shown in Figure 2. Students were asked what they liked the most, what they liked the least, what they would like more of, what would be their preferred course format, and whether they believed that

DOI: 10.1021/ed500537b
J. Chem. Educ. XXXX, XXX, XXX−XXX

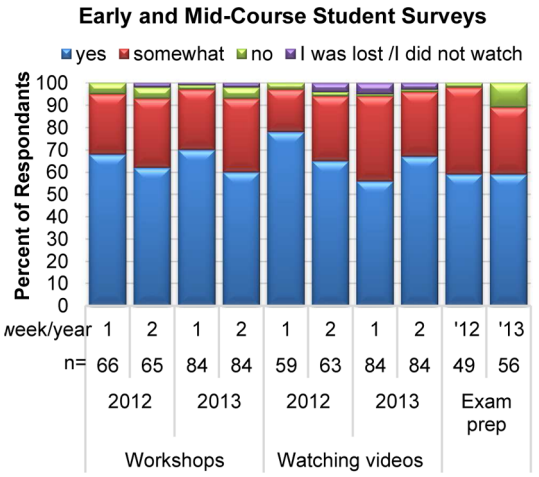


Figure 1. Results of student surveys. Questions were: (1) I believe that workshops are an effective way to learn course material. (2) Watching course videos prepared me for workshops. (3) Workshops are an effective way to prepare for exams.

working in a group setting was an effective way to learn the course material. After the first year of the course transformation in 2012, 41% of the students reported that the activity that they liked the least was the workshops. When asked to explain their reasons, 38% of the 63 students who responded indicated that some group members were unprepared, or they expressed some sort of dissatisfaction with members of their group. Other reasons given were insufficient time to complete the group assignment (22%), not enough LAs to assist with problems (13%), LAs were not equally prepared (13%), the classroom set-up was not ideal for group work (8%), workshops were too frequent (8%), or they took away too much time from lecture (8%).

Adjustments in Response to End of Course Surveys

In 2012, small groups were assigned at random before the first exam. After the first exam, groups were assigned in such a way that each group would have a similar grade distribution based on exam scores. These groups stayed together for the remainder of the semester (eight workshops). Group problem assignments contributed to the student's final grade (12%) in both years. It was therefore important that each group member come prepared and contribute to the group effort. Highly motivated students expressed their frustration with students who were unmotivated or struggling with the material. Students who found the material highly challenging felt intimidated by the highly achieving students. Mindful of student complaints about group dynamics, workshop groups were managed differently in 2013. Groups were again assigned at random before the first exam and reassigned after each exam in such a way that each group would have a similar grade distribution, and no two students would be in the same group twice. This way, each group was together for only four workshops. In addition, five students who failed the first exam but who appeared to make an effort to complete online assignments were grouped together, and an LA was assigned exclusively to this group. Ultimately, three of those students dropped the class, one completed the class with a D, and the fifth student completed the class with a C.

In response to student comments about insufficient time to complete the assignments, a second adjustment to workshops was made. Each workshop included practice problems that were not graded for which the students received assistance from the professor or LAs and a set of problems that were solved without assistance and turned in for a group grade. The graded problem set should have been straightforward after the students mastered the practice problems. In 2012, students were given both problem sets during the workshop. When taught in 2013, practice problem sets were assembled into a booklet that was distributed to the students at the beginning of the semester, which provided the opportunity to be better prepared for workshop days.

While it was not practical to increase the number of LAs because of limited resources, it was possible to ensure that all LAs were prepared through weekly meetings prior to the workshop. Finally in 2013, the course was moved from a fixed-seating format to a more appropriate classroom. These adjustments, which addressed the majority of the student complaints pertaining to workshops, resulted in statistically significant increases, shown in Table 2, in the percentage of students who reported that they liked workshops the most (from 10% in 2012 to 25% in 2013, $\chi^2 = 5.09$, $p = 0.02$) and

Table 2. Statistical Analysis of the Change in Students' Survey Responses Shown in Figure 2

Indicated Response versus Sum of All Other Responses		
Response	χ^2	p
Liked workshops the most	5.09	0.02
Liked workshops the least	4.29	0.04
Wanted more workshops	3.83	0.05
Wanted more videos	3.09	0.08
Wanted more case studies	1.55	0.21
Prefered a traditional lecture	0.82	0.36
Prefered 50% inverted	1.44	0.23

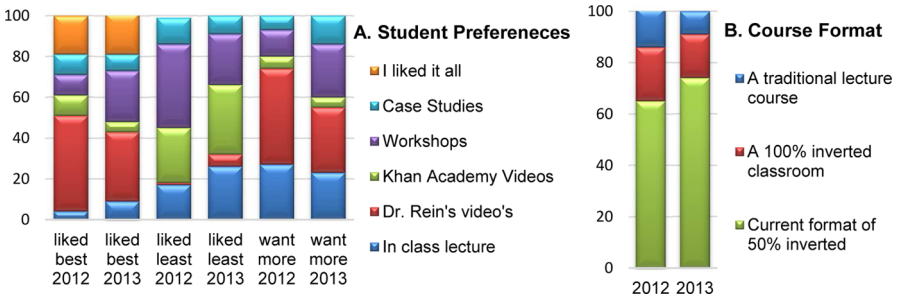


Figure 2. End of course survey. (A) Students were asked what components of the course the liked best, liked least, and wanted more. (B) Students were asked their preference of course format. ($n = 70$ for 2012, $n = 65$ for 2013).

DOI: 10.1021/ed500537b
J. Chem. Educ. XXXX, XXX, XXX−XXX

wanted more workshops (from 13% to 26%, $\chi^2 = 3.83$, $p = 0.05$) and a concomitant decrease in the percentage of students who reported that they liked workshops the least (from 41% to 25%, $\chi^2 = 4.29$, $p = 0.04$).

Students reported that the activity that they liked the most (47% the first year and 34% the second year, $\chi^2 = 3.09$, $p = 0.08$) was watching the videos that were prepared specifically for their course. Additionally, 47% of students surveyed in the first semester indicated that the activity that they would like more of was course videos. Between 2012 and 2013, the number of videos available increased from 43 to 57. This may account for the reduction in the number of students reporting that they would like more videos in 2013. On the other hand, a number of Khan Academy videos was assigned and was among the most disliked activities. This was somewhat surprising. However, it may be that these videos are overly detailed for a one-semester course.

Student response to case studies was neither overwhelmingly positive nor negative regardless of the manner in which they were incorporated into the class or graded: 10% and 8% (2012 and 2013 respectively) reported they liked case studies the most, and 13% or 9% reported that they liked case studies the least. The number of students who reported that they wanted more case studies doubled between 2012 and 2013, from 7% to 14%. However, the change was not statistically significant ($\chi^2 = 1.55$, $p = 0.21$).

When asked about course format, the majority of students in both semesters indicated that they prefer the current course format of 50% inverted (67% and 74%) over either a traditional lecture course (15% and 9%) or a completely inverted course (21% and 17%). These changes were also not statistically significant ($\chi^2 = 0.82$, $p = 0.36$; $\chi^2 = 1.44$, $p = 0.23$). However, we did not anticipate that they would be statistically significant. Even though students reported that they prefer videos over lecture, they do seem reluctant to give up lectures entirely; however, it may be argued that this reluctance to move to a completely inverted course may be a fear of the unknown. On the other hand, 15% or fewer of the students indicated that they would prefer a traditional lecture course, and these students were certainly familiar with a traditional format.

Student Assessment of Instruction

The student assessment of instruction is a 15-question end-of-course evaluation used by the author's institution to evaluate teaching. Significant improvements were recorded in responses to most categories from 2011 to 2012 and in *all* categories from 2011 to 2013. Select results are shown in Figure 3 with statistical analysis of survey results shown in Table 3. Most noteworthy are improvements in "facilitation of learning", "stimulation of interest in the course", and "communication of ideas and information". A more modest increase in student perception of "use and management of class time" was recorded.

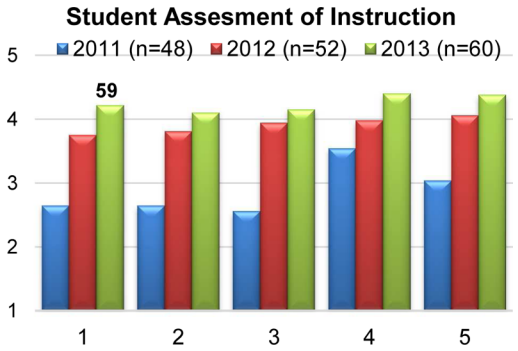


Figure 3. Average of values from the student assessment of instruction (*y*-axis; 5 = excellent; 1 = poor). Number of respondents (2011, Question 1) noted above the bar. Questions (*x*-axis): (1) Facilitation of Learning, (2) stimulation of interest in the course; (3) communication of ideas and information; (4) use and management of class time; and (5) overall assessment of instruction.

■ DISCUSSION

While it is disappointing that students did not perform any better on exams after the intervention, our null result adds to a growing body of literature on the limitations and successes of reformed instructional methods such as guided inquiry, case studies, and the inverted classroom. Some studies have demonstrated the effectiveness of the inverted classroom approach in changing students' attitudes[17] and improving learning.[18] However, He et al. did not observe a statistically significant improvement in overall grades in an analytical chemistry course using online video tutorials.[19] Likewise, Dinan did not observe a change in overall grades in a team-based organic chemistry class.[20] More recently, Christiansen reported no gains in student exam scores from an inverted organic chemistry class when compared to a traditional lecture format (although the sample sizes were quite small).[21] Conway observed larger gains in student performance in a nonmajors organic/biochemistry course when the course was exclusively POGIL over a half-POGIL course when compared to a traditional lecture format.[5] Another key factor that should be considered is the alignment between instructional methods and assessments. To facilitate a direct comparison between traditional and reformed instruction, the author made an effort to keep the exam questions similar across the years. However, several researchers have argued that if the learning goals and activities change, then the assessments should also change to align more closely with those new learning goals.[11,22,23]

Partial inversion and incorporation of collaborative learning and case studies into an organic chemistry course for nonchemistry majors was generally well received by students. Students overwhelmingly preferred watching videos over lecture. Students commented that because the videos were brief, their attention did not wander and that they could rewind when they did miss an important point and view the videos as many times as needed. It may not be necessary for faculty to prepare their own course videos as there are literally hundreds of chemistry-related instructional videos to choose from on YouTube. However, instructors are cautioned to choose carefully. Many of these videos are geared toward science majors, and nonmajor students dislike watching videos that they believe are overly complex or detailed or not directly related to their course. Students felt that solving problems in small groups was an effective strategy to learn the material and reported that when they had problem sets ahead of time, they were better able to identify key points in the videos and were better prepared for workshops even if they did not attempt the problems prior to the class period.

Our most important finding from this research is that group dynamics significantly influenced student perception of the value of group problem sessions (workshops). It was only by implementing a detailed evaluation where students could give open-ended written feedback that we were able to uncover the problem, understand its source, and address it. Facilitation of

DOI: 10.1021/ed500537b
J. Chem. Educ. XXXX, XXX, XXX−XXX

Table 3. Statistical Analysis of Results for the Student Assessment of Instruction

Pair-Wise Comparison *p*-Values (Two-Tailed *t*-Test)			
Survey question	2011−2012	2011−2013	2012−2013
Facilitation of learning	2.5×10^{-5}	6.1×10^{-10}	3.2×10^{-2}
Stimulation of interest in the course	1.1×10^{-6}	5.4×10^{-10}	0.15
Communication of ideas and information	2.9×10^{-7}	5.6×10^{-10}	0.31
Use and management of class time	0.12	1.9×10^{-4}	2.4×10^{-2}
Overall assessment of instructor	3.7×10^{-5}	1.4×10^{-8}	8.5×10^{-2}

group interactions is arguably the most difficult aspect to predict or control. By shuffling the groups several times during the semester, before resentments could develop, and by separating the students who were struggling with the material from the rest of the class, we were able to significantly improve the students' views of and attitudes toward group work. However, singling out the students who were struggling with the material for extra attention made little difference in the outcome and may be too large a commitment of limited resources for very little return.

Significant improvements in the responses to several questions on the end-of-course evaluation were observed, in particular, "stimulation of interest in the course". We attribute this increase to the incorporation of case studies, even though the student response to case studies was neutral (they neither liked them best nor least). We attribute the increase in student response to "facilitation of learning" to the incorporation of problem-solving activities. To our surprise, an increase in the response to "management of class time" was observed for the transformed course. Loss of control in the classroom is perhaps another reservation among instructors for incorporation of active learning methods. Workshops seemed chaotic to the instructor, and we anticipated that the incorporation of workshops would result in a decrease in student perception of "management of class time". Clearly the students had a different perception from that of the instructor. It is difficult to interpret the increased response to "communication of ideas and information" when identical PowerPoints (either real time or recorded) covering the same material were presented by the same instructor. This may simply reflect the students' overall satisfaction with the course or increased confidence in their mastery of the material.

A major reservation that science faculty have with respect to both the inverted classroom and the case-study method of teaching is that both methods reduce the time available for content delivery. This reservation is certainly valid in particular for a high-content course such as organic chemistry. However, Dinan reported covering 16 chapters after implementation of a team-based learning method in an organic chemistry class compared to the 14 chapters covered in the traditional lecture course.[20] In the case reported here, the traditional course coverage varied over the years between 12 and 13 chapters. Both semesters that the transformed course was taught, 12 chapters were covered. In a course for nonmajors, it is easier to justify reducing the volume of material. The benefits of a small reduction in content for group activities include enhancement of critical thinking and social skills needed to work effectively as part of a team. Perhaps more important, students may have a deeper understanding of fundamental concepts and an appreciation for the connections that organic chemistry has to the world around them through case studies. A recent article urges chemistry instructors not to "ignore the wonder" when teaching chemistry by over emphasizing the text while compromising this important pedagogical goal.[24] This admonition is particularly relevant for instructors of courses for nonmajors.

From the faculty perspective, the incorporation of guided-inquiry instruction can be intimidating but in the long run is a far more rewarding approach to teaching. The author had an actual conversation with every student taking the transformed course. It is extremely gratifying to look out at a classroom full of students who are actively engaged and arguing over how to solve problems rather than watching the clock or struggling to stay awake.

AUTHOR INFORMATION

Corresponding Author

*E-mail: reink@fiu.edu.

Notes

The authors declare no competing financial interest.

ACKNOWLEDGMENTS

This work was supported by Howard Hughes Medical Institute Grant No. HHMI 52006924.

REFERENCES

(1) Udo, M. K.; Ramsey, G. P.; Mallow, J. V. Science Anxiety and Gender in Students Taking General Education Science Courses. *J. Sci. Educ. Technol.* **2004**, *13*, 435−446.

(2) Van Sant, G. *Good Will Hunting* [DVD]; Miramax Films: Santa Monica, CA, 1997.

(3) Smith, J. D. Student Attitudes toward Flipping the General Chemistry Classroom. *Chem. Educ. Res. Pract.* **2013**, *14*, 607−614.

(4) Ferreri, S. P.; O'Connor, S. K. Redesign of a Large Lecture Course into a Small-Group Learning Course. *Am. J. Pharm. Educ.* **2013**, *77*, 13−22.

(5) Conway, C. J. Effects of Guided Inquiry versus Lecture Instruction on Final Grade Distribution in a One-Semester Organic and Biochemistry Course. *J. Chem. Educ.* **2014**, *91*, 480−483.

(6) Etkina, E.; Mestre, J. P. Implications of Learning Research for Teaching Science to Non-Science Majors. *SPENCER Backgrounder* 1−25.

(7) Felder, R. M.; Brent, R. Navigating the Bumpy Road to Student-Centered Instruction. *Coll. Teach.* **1996**, *44*, 43−47.

(8) Allen, G. K.; Wedman, J. F.; Folk, L. C. Looking beyond the Valley: A Five-Year Case Study of Course Innovation. *Inn. High. Educ.* **2001**, *26*, 103−119.

(9) Korthagen, F. A. J.; Kessels, J. P. A. M. Linking Theory and Practice: Changing the Pedagogy of Teacher Education. *Educ. Res.* **1999**, *28*, 4−17.

(10) Black, P.; Wiliam, D. Inside the Black Box: Raising Standards through Classroom Assessment. *Phi Delta Kappan* **1998**, *80*, 139−148.

(11) Eberlein, T.; Kampmeier, J.; Minderhout, V.; Moog, R. S.; Platt, T.; Varma-Nelson, P.; White, H. B. Pedagogies of Engagement in Science. *Biochem. Mol. Biol. Educ.* **2008**, *36*, 262−273.

(12) Lage, M. J.; Platt, G. J.; Treglia, M. Inverting the Classroom: A Gateway To Creating an Inclusive Learning Environment. *J. Econ. Educ.* **2000**, *31*, 30−43.

DOI: 10.1021/ed500537b
J. Chem. Educ. XXXX, XXX, XXX−XXX

(13) Smith, C. M.; McDonald, K. The Flipped Classroom for Professional Development: Part II. Making Podcasts and Videos. *J. Cont. Educ. Nurs.* **2013**, *44*, 486−487.
(14) D'Angelo, J. G. D. Use of Screen Capture To Produce Media for Organic Chemistry. *J. Chem. Educ.* **2014**, *91*, 678−683.
(15) Herreid, C. F. Case Studies in Science—A Novel Method of Science Education. *J. Coll. Sci. Teach.* **1994**, *23*, 221−229.
(16) Dewprashad, B. *The Chemistry of Curcumin, the Health Promoting Ingredient in Turmeric*; National Science Foundation: Arlington, VA. http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=275&id=275 (accessed May 7, 2014).
(17) Strayer, J. F. How Learning in an Inverted Classroom Influences Cooperation, Innovation, and Task Orientation. *Learn. Environ. Res.* **2012**, *15*, 171−193.
(18) Fulton, K. Upside-Down and Inside-Out: Flip Your Classroom To Improve Student Learning. *Learn. Leading Technol.* **2012**, *39*, 12−17.
(19) He, Y.; Swenson, S.; Lents, N. Online Video Tutorials Increase Learning of Difficult Concepts in an Undergraduate Analytical Chemistry Course. *J. Chem. Educ.* **2012**, *89*, 1128−1132.
(20) Dinan, F. J.; Frydrychowski, V. A. A Team Learning Method for Organic Chemistry. *J. Chem. Educ.* **1995**, *72*, 429−431.
(21) Christiansen, M. A. Inverted Teaching: Applying a New Pedagogy to a University Organic Chemistry Class. *J. Chem. Educ.* **2014**, *91*, 1845−1850.
(22) Hannafin, M. J.; Land, S. M. The Foundations and Assumptions of Technology-Enhanced Student-Centered Learning Environments. *Instr. Sci.* **1997**, *25*, 167−202.
(23) Brookes, D. T.; Etkina, E. In Search of Alignment: Matching Learning Goals And Class Assessments. In *Proceedings of the 2011 Physics Education Research Conference*; Rebello, N. S., Engelhardt, P. V., Singh, C., Eds.; American Institute of Physics: Melville, NY, 2012; Vol. *1413*, pp 11−14.
(24) Amaral, K. E.; Shibley, I. A., Jr. Using Popular Nonfiction in Organic Chemistry: Teaching More than Content. *J. Chem. Educ.* **2010**, *87*, 400−404.

DOI: 10.1021/ed500537b
J. Chem. Educ. XXXX, XXX, XXX−XXX