



Student Perceptions of Lecture-Capture Video to Facilitate Learning in a Flipped Classroom

Ying Xiu¹ · Michael Edward Moore² · Penny Thompson³ · Donald P. French⁴

Published online: 28 April 2018

© Association for Educational Communications & Technology 2018

Abstract

Use of flipped learning environments, where content is delivered online outside of class and class time features student-centered activities, is an increasingly popular way to facilitate active learning. The success of classroom activities, however, depends on students' willingness to complete the out-of-class work and come to class well prepared. Therefore, it is important for instructors to understand students' attitudes towards required pre-class preparation. This study used an online questionnaire, featuring both Likert-type and open-ended questions, to explore students' attitudes towards the online video used in a flipped undergraduate science class. Results showed moderately positive attitudes toward the pre-class video lecture, but also some strongly negative attitudes. Results of this study can help instructors understand both the benefits of flipped learning from the student perspective and the likely sources of resistance. This understanding can help instructors anticipate students' concerns and provide effective orientation when introducing the flipped learning model in undergraduate courses.

Keywords Flipped learning environments · Video · Student perceptions

Active learning instruction, where students are actively engaged rather than passively listening to traditional lecture, has been shown to improve student academic performance (Freeman et al. 2014). A flipped learning environment is one way to provide more time for active learning than one would have using more traditional instructional methods. A flipped

classroom is “an educational technique that consists of two parts: interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom” (Bishop and Verleger 2013, p. 5). Thus, the flipped model moves the content delivery process outside the classroom so class time can be devoted to instructor-facilitated active learning.

Active learning instruction is designed to help students practice and build connections with information they have previously learned (Bonwell and Eison 1991). Therefore, for students in flipped learning classrooms to experience the greatest benefit from their participation during active learning instruction, they must spend time acquiring base knowledge and preparing for the class (Burke and Fedorek 2017). Content acquisition before class and participation during active learning instruction in class are significant predictors of, and account for a significant portion of the variation in, exam grades (Moore et al. 2018. Using preparation and practice as predictors of performance in flipped learning classrooms (unpublished data)). Different factors could affect content acquisition in flipped learning environments, such as delivery medium. One of the most widely accepted vehicles used for content dissemination in flipped classes is the video lecture (Herreid and Schiller 2013). Because student attitudes towards a delivery

✉ Ying Xiu
yxIU@okstate.edu

Michael Edward Moore
michael_e_moore@baylor.edu

Penny Thompson
penny.thompson@okstate.edu

Donald P. French
donald.french@okstate.edu

- ¹ Oklahoma State University, 205 Willard Hall, Stillwater, OK 74078, USA
- ² Baylor University, One Bear Place #97388, Waco, TX 76798-7388, USA
- ³ Oklahoma State University, 210 Willard Hall, Stillwater, OK 74078, USA
- ⁴ Oklahoma State University, 501 Life Science West, Stillwater, OK 74078-3052, USA

medium can influence their learning (Sankaran et al. 2000), it is important to understand student attitudes toward video lectures in a flipped learning environment.

Literature Review

Student Attitudes about the Flipped Classroom

Research on student attitudes toward the flipped classroom suggest that students have an overall positive opinion. In Bishop and Verleger's (2013) literature review of 13 studies published through 2012, students generally liked the flipped classroom, particularly because they liked the in-class activities. However, some studies included in the review showed that students preferred live lectures over video lectures, and some reported strongly negative feelings towards the flipped classroom. A more recent study by Blair et al. (2016) compared a flipped classroom with the same class taught in a traditional format in the previous year, and found that students' end-of-term course evaluations were significantly higher in the flipped condition. Specifically, students in the flipped classroom gave higher scores on questions related to "presentation of material, assignments, and online components" (p. 1474). Kim et al. (2014) explored whether a Community of Inquiry (Garrison et al. 2000) could be achieved in a flipped classroom. Students expressed positive attitudes toward the flipped class, perceiving it as a student-centered environment that also included high levels of teaching presence. Tawfik and Lilly (2015) found the flipped model supported students in a problem-based learning environment, where the videos served as resources that students could review as needed to scaffold their problem-solving activities.

Some studies have found neutral or mixed reactions to the flipped classroom. Hao (2016) studied two flipped university courses and found that "about 60% of the students recognized the advantages of flipped classrooms" (p. 89), but responses to open-ended questions showed a mix of positive and neutral attitudes, with a few highly negative comments about the workload. The outside-of-class work in this study, however, consisted of a mix of curated online videos, audio-only lectures, and textbook readings, rather than the more typical reliance on instructor-created or curated video lectures, so it is possible that the audio-only and print materials were perceived as more burdensome than video. Lape et al. (2015) compared flipped and traditional sections of university courses in math and engineering. In these courses the traditional condition did include some active learning in the classroom, but the flipped condition featured it more heavily. While only preliminary results were reported in this study, no significant differences between conditions were found in students' attitudes or motivation. In a single group study of university students by Smith (2013), 97% of students reported finding the recorded lectures useful, but

48% also said they found the time commitment burdensome. Chen et al. (2014) compared two different types of flipped classroom, and found that students reported benefits to the flipped format but that "students may have resisted adopting this model because their old, passive learning habits required less effort" (p. 26). In summary, studies of student attitudes toward the flipped classroom at the university level seem to show overall positive attitudes, but also suggest that a segment of the student population holds unfavorable attitudes towards use of video lectures as out-of-class work.

Learning in the Flipped Classroom

While early research on the flipped classroom has focused heavily on student perceptions and less on objective measures of learning (Bishop and Verleger 2013), some studies have attempted to assess learning gains as well, with mixed results. Entezari and Javdan (2016) found that community college students in a flipped introductory physiology class performed significantly better on exams than students in an equivalent course taught in a traditional format. Blair et al. (2016) found students liked the flipped classroom more but did not perform better on achievement measures. Gross et al. (2015) compared the timing and frequency of students' interactions with the online material in a flipped classroom and a traditional classroom with online resources, and found that students in the flipped environment used the online materials more frequently and more consistently throughout the semester. This increase in timely interaction with pre-class material correlated with increased student learning outcomes. Ryan and Reid (2016) found that the positive effect of the flipped classroom was only significant for lower performing students, as shown in a reduction in students receiving D's or F's or withdrawing from the course. This research shows that the learning gains from a flipped class may only be experienced by a subset of students and not by all students equally. Overall, research thus far suggests that flipped learning is either beneficial or neutral with respect to student learning.

Connections Between Student Attitude and Student Performance

Student attitudes towards the course format have been associated in some studies with student performance. Lee et al. (2005), for example, found that students were more likely to use provided internet-based resources if they perceived them to be useful and enjoyable. Sankaran et al. (2000) found that students with high scores on a scale measuring their attitudes towards web-based learning performed better in online courses than students who scored lower on the scale, though there was no significant overall difference in learning between students taking a web-based version of a course and those taking the face-to-face version. This suggested students

performed best when there was a *match* between their preferred format and the course format. Since the out-of-class portion of the flipped learning model generally involves watching instructor-created or curated videos to deliver content, students' initial attitudes towards learning from video could influence their perceptions of the flipped learning environment and their subsequent performance in this type of course. The purpose of this study was to explore students' attitudes towards flipped learning in general and the use of pre-class video in particular, and to gain further insights into the perspectives of students with negative attitudes. We sought to address the following research questions:

1. What are students' attitudes towards the pre-class videos in a flipped learning environment?
2. What reasons do students give for their positive and negative attitudes toward flipped learning?

Methods

Context

This study was conducted in the context of an introductory honors biology course, taught in flipped classroom format, at a large land grant university in the Midwest with a Carnegie classification of "higher research activity." The course was open to biology majors and non-majors, and the majority of students enrolled were freshmen and sophomores. This course was typically the students' first university-level science course and their first experience with flipped learning.

The flipped course format featured three weekly face-to-face class meetings plus a course website on the university's Desire-2-Learn learning management system. The course website provided a variety of resources for the students, including required video lectures to be watched before each in-class session (see the [Online Activities](#) section below). The course also included a separate three-hour weekly lab session.

Instead of chapters or units, the course was organized around scenarios or stories that were used to connect multiple topics to one central theme. For example, the scenario entitled "chemical defenses" includes concepts such as chemical gradients, neurotransmission, and transcription and translation. Each scenario encompassed up to six class periods and three to six related pre-class lecture videos.

Online Activities

Online activities consisted of video lectures, guiding questions to support viewing the videos, and quizzes on the video content. The pre-class videos delivered basic content knowledge, and were edited recordings of inquiry-based (Lazonder and

Harmsen 2016) lectures from past semesters before the class was transitioned to the flipped learning model. These 50-min videos were reduced to 35–40 min videos by cutting the portions of the video where the in-class students completed class activities or asked non-content related questions (e.g., exam time and location). Lecture videos that exceeded 40 min were cut into two videos to make them easier to watch. Accompanying each video lecture was a "question packet" (a worksheet students filled out) designed to help focus the students' attention on the important concepts in the lecture video. At the end of each scenario, students were required to take a short reflective quiz to unlock the next scenario.

In-class Instruction

Watching videos outside of class allowed class time to be used for a variety of activities, such as small group and whole class discussions, sometimes using classroom response devices ("clickers") to help students sharpen their knowledge of biology. The use of clickers provides just one example of the active learning strategies applied in the classroom. A question was posed and students were given thirty seconds to answer the question using their clickers. The instructor would then show the distribution of their choices. If the percentage of students selecting the correct answer was lower than 80, the instructor would ask the class to discuss the question in small groups, after which time the instructor would repeat the poll to see if there was a shift in the answer distribution. This process of discussion and re-polling would continue until 80% of attending students answered the question correctly. Other classroom activities involved similar levels of student interaction and interactivity.

Participants

Participants were recruited from an honors biology class with an enrollment of 80 students who entered the course with a mean GPA of 3.8. Sixty-nine of these students consented to participate in the study, and 62 of those (48 female, 14 male) completed the entire questionnaire. Fifty-four of the respondents were freshman, while the remainder were sophomores, juniors, and seniors. Fifty-one respondents were white, while the remainder identified themselves as members of other racial groups. Additional demographic details are not reported here because some categories were too small to ensure participant anonymity.

Measures

The primary measure in this study was a modified version of a questionnaire used by Long et al. (2016) to explore students' opinions about flipped learning. The questionnaire included fifteen Likert-type questions, two short answer questions, and

three open-ended questions (see [appendix](#)). To make the survey manageable, it was broken into three parts, which were disseminated at different points during the semester through the course learning management system. Twelve of the Likert-type questions and the short answer questions were incorporated into the quizzes students completed after viewing required pre-class videos. The remaining three Likert-type questions and the open-ended questions were asked as part of a final course survey.

Data Analysis

Responses to the Likert-type questions were analyzed with descriptive statistics. Of the three open-ended questions, only the first was determined to provide enough data to address the research questions. Sixty of the 62 participants responded to this question. Three researchers, including one faculty member and two doctoral students, reviewed these comments individually and, in addition to noting the specific attributes of the video discussed by participants, analyzed the emotional valence of the comments. Working independently, each researcher assigned a score to each participant response by assigning a “1” to every positive or favorable comment about the videos, a “-1” to every negative comment, and a “0” to every neutral comment. A net score was then computed by adding the positive and negative numbers. For example, a comment that said, “the videos were really boring but I did learn from them, and they helped me study for tests” would receive a score of “1,” because it contained one negative comment (“boring”) and two positive comments (“I did learn from them” and “they helped me study”). After scoring the comments individually, the three researchers discussed each participant comment where their numerical scores differed. After all areas of disagreement were addressed, either by reaching consensus or agreeing to disagree, a Fleiss Kappa inter-rater agreement level of 0.928 was achieved.

Findings

Analysis of the Likert-type questions based on Long et al. (2016) showed the scale had a high level of internal consistency, with a Cronbach’s α value of 0.873 (Cronbach 1951). Descriptive statistics show that overall, students expressed neutral to slightly positive opinions about the different activities that made up this flipped learning environment. Students expressed the least positive opinions about how well the quizzes helped them understand the video, with a mean score of 2.97 (SD = .97) on the five-point scale. The highest rating was for the value of the in-class activities, with a mean of 4.19 (SD = 1.01). Mean ratings for other questions ranged from 3.34 to 3.98, as shown in Table 1.

Table 1 Students’ perceptions about learning activities in a flipped classroom ($N = 62$)

Statement	Mean	SD
I like viewing pre-class videos better than reading text materials	3.66	1.31
The videos were helpful because I could do them on my own time.	3.82	1.11
The videos were easy to learn from.	3.34	1.08
The topics were well-explained in the videos.	3.45	0.82
The videos were helpful for completing the scenario quizzes over scenario material.	3.48	0.98
The videos were helpful for completing the in-class activities.	3.98	0.99
The scenario quizzes helped me understand the knowledge covered in the videos.	2.97	0.97
The in-class activities helped me understand the knowledge covered in the videos.	4.19	1.01

The two short answer questions pertained to how long participants felt they could watch a video lecture before they began to feel tired or lose focus. Of the 60 participants who responded to this question, three outliers who listed times of 120 min or longer were removed from the analysis, as all other responses were 60 min or below. The remaining 57 valid responses are summarized in Table 2.

Analysis of the emotional valence of the open-ended comment (see Fig. 1) showed a range of -4 to $+5$, with one outlier scoring -7 . The distribution of rankings was negatively skewed and had a mode of $+2$. Fifty-nine percent of participants had scores of 2 or higher.

One positive aspect of the videos identified by several students was the ability to pause the video or replay sections as needed. For example, one student said, “I appreciated that I was able to pause the lecture or re-watch parts of it because it made it easier for me to take notes or look things up that I didn’t completely understand.” Other positive aspects of the video included the flexibility of accessing the videos at any time from anywhere (“I could do the videos on my own time”), and the utility of the video for review before exams (“They are especially helpful when needing refreshers on a topic”).

While a few of the negative comments were vague (“I found them to be boring and a waste of time”), most were quite specific. The negative features mentioned included frustration with not being able to ask questions (“I cannot ask questions,

Table 2 Students’ perceptions about video length ($N = 57$)

Question	Mean	SD
I can typically watch a video for _____ minutes before I begin to feel tired.	29.04	16.37
I can typically watch a video for _____ minutes before I start to lose focus.	23.44	13.00

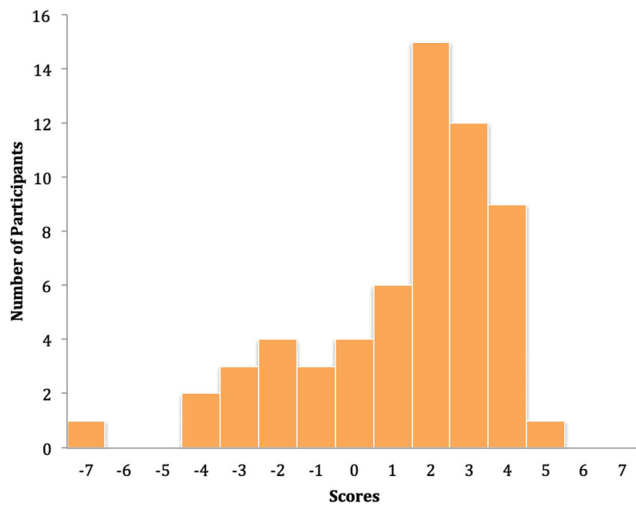


Fig. 1 Distribution of numerical scores on open-ended questions ($N=60$)

like in a real classroom setting”), and a perception that the videos required more time than traditional homework assignments (“They took up my time outside of class, when I needed to be attending to other things”). One student perceived the flipped classroom as an abdication of instructor responsibility (“I hated having to sit and watch an hour or two of videos outside of class, when class time is for lecturing by the professor”). Similarly, the comment noted above regarding “a real classroom setting” implied that the online instruction was not “real” teaching. These comments suggested that while the overall perception of the pre-class videos was positive, some students experienced substantial frustration and, in some cases, resistance to the entire flipped learning concept.

Discussion and Concluding Remarks

Our first research question explored students’ attitudes towards the pre-class videos in a flipped learning environment. The quantitative data indicate students held overall moderately positive attitudes toward the pre-class videos, though their feelings about the video were not as strongly positive as their feelings about the in-class activities. On average, students reported an ability to maintain focus on a lecture video for up to about 23 min. This result is somewhat surprising in light of the findings by Guo et al. (2014), who examined data analytics in MOOC courses and found that students only watched each video for an average of six minutes. However, the self-reported 23-min preference found in the current study falls within the 20 to 30 min range reported as a preferred video length by Long et al. (2016). While more research is needed to explain this discrepancy, it is possible that students’ self-reports of their engagement with video do not match their actual behavior when watching video.

Our second research question explored participants’ specific reasons for both positive and negative attitudes toward

flipped learning. Responses to the open-ended question were consistent overall with the moderately positive reactions to the videos found in the quantitative data, and highlighted some specific advantages of video, such as the ability to pause to take notes, to review portions as needed, and to access the video lecture at a time most convenient for the students. At the same time, the responses to the open-ended question revealed a “long tail” of strongly negative perceptions about the pre-class videos and perhaps the flipped learning environment itself. These negative comments focused on both the features of learning from video (such as the inability to ask questions immediately) and on students’ perceptions of the appropriate role of the instructor in a face-to-face classroom and the perception that watching videos was more burdensome than other forms of homework.

The negative perceptions expressed by student in this study are consistent with those found by Owens et al. (2017) in their study of student perceptions of an active learning classroom. They found that students resisted active learning for a number of reasons. Students often didn’t understand the purpose of the classroom activities and viewed the critical thinking skills they were developing through active learning as less important than content memorization. Some were uncomfortable grappling with uncertainty and preferred a more authoritative presentation of information, or disliked the extra effort required to prepare for class and participate in the in-class learning activities. Students who resist flipped or active learning may be at risk of feeling alienated from the course, which may lead to reduced interaction with course materials (Johnson 2005). In a flipped classroom, this reluctance to make use of the pre-class material can result in lower academic achievement in the class (Burke and Fedorek 2017).

More research is needed to find ways to overcome resistance to and inaccurate perceptions of flipped learning (e.g., perceptions that the instructor is not doing his or her job) to prevent and reach these reluctant students before they become alienated and disengaged from the course. Owens et al. (2017) suggested a number of steps instructors could take to overcome resistance to active learning, which could potentially improve attitudes and video-watching in a flipped environment as well. Their suggestions included scaffolding students’ preparation for class by providing resources and questions, making sure expectations are clear and assessments are consistent with the active learning pedagogy, and providing information and evidence to demonstrate the value of active learning. In a flipped environment, this may include providing links to external video resources as a supplement to the required videos, providing questions to scaffold comprehension of the video (as was done in the “question packets” in this study), and explaining the rationale for the flipped environment, in the form of an orientation at the beginning of the term and reminders throughout. At the same time, the self-directed learning needed for success in a flipped learning environment

is not always comfortable for students accustomed to a more structured, didactic pedagogy, and making students comfortable is not a necessary or desirable goal. It is unavoidable that student will experience “a bit of resistance on their way from intellectual dependence to autonomy” (Owens et al. 2017, “Student Resistance,” para. 3).

A limitation of this study is that participants were honor students, who may therefore have different characteristics with respect to motivation and achievement than undergraduate students in non-honors courses. In addition, the study was based on students’ self-reported perceptions, so does not directly address how well the videos supported their learning.

This study contributes to knowledge about flipped learning by partially replicating the study done by Long et al. (2016), adding additional data about student perceptions of the use of video in a flipped science classroom. Beyond this, however, it also highlights specific sources of student resistance to flipped learning. This greater understanding of students’ attitudes about pre-class video can alert instructors to the need to address the concerns of reluctant students, thus enabling the potential benefits of the flipped environment to reach more students. In addition to providing an orientation to flipped learning at the beginning of the term, instructors might be wise to monitor student feedback formatively and intervene during the semester if students seem disengaged. As flipped learning environments grow more popular, research will be needed to address the sources of student frustration and resistance, so that all students can realize the benefits of this coupling of “anytime, anywhere” content delivery and active classroom learning.

Compliance with Ethical Standards

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Appendix

Likert Questions:

1. I like viewing pre-class videos better than reading text materials*.
2. The videos were helpful because I could do them on my own time. *
3. The videos were easy to learn from. *
4. The topics were well-explained in the videos. *
5. The videos were helpful for completing the scenario quizzes over scenario material*.

6. The videos were helpful for completing the in-class activities. *
7. The scenario quizzes helped me understand the knowledge covered in the videos. *
8. The in-class activities helped me understand the knowledge covered in the videos. *

Short Answer Questions:

1. I can typically watch a video for _____ minutes before I begin to feel tired.
2. I can typically watch a video for _____ minutes before I start to lose focus.

Open-ended Questions:

1. Do the pre-class lecture videos help you learn biology? Why? How?
2. Is there anything else you would like to tell us about the videos you watched for this class?
3. Do you have any other suggestions for how the course could be improved to help you learn better?

* = Items adapted from Long et al. (2016).

References

- Bishop, J.L., & Verleger, M.A. (2013). The flipped classroom: A survey of the research. *Proceedings of the ASEE National Conference*, Atlanta, GA.
- Blair, E., Maharaj, C., & Primus, S. (2016). Performance and perception in the flipped classroom. *Education and Information Technologies*, 21(6), 1465–1482. <https://doi.org/10.1007/s10639-015-9393-5>.
- Bonwell, C. C., & Eison, J. A. (1991). *Active learning: Creating excitement in the classroom. 1991 ASHE-ERIC higher education reports*. Washington, DC: Association for the Study of higher education. Retrieved from: <https://files.eric.ed.gov/fulltext/ED336049.pdf>
- Burke, A. S., & Fedorek, B. (2017). Does “flipping” promote engagement?: A comparison of a traditional, online, and flipped class. *Active Learning in Higher Education*, 18(1), 11–24. <https://doi.org/10.1177/1469787417693487>.
- Chen, Y., Wang, Y., & Chen, N. S. (2014). Is FLIP enough? Or should we use the FLIPPED model instead? *Computers & Education*, 79(1), 16–27. <https://doi.org/10.1016/j.compedu.2014.07.004>.
- Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, 16, 297–334.
- Entezari, M., & Javdan, M. (2016). Active learning and flipped classroom, hand in hand approach to improve students learning in human anatomy and physiology. *International Journal of Higher Education*, 5(4), 222–231. <https://doi.org/10.5430/ijhe.v5n4p222>
- Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 111(23), 8410–8415. <https://doi.org/10.1073/pnas.1319030111>.
- Garrison, D. R., Anderson, T., & Archer, W. (2000). Critical inquiry in a text-based environment: Computer conferencing in higher

- education. *The Internet and Higher Education*, 2(2–3), 87–105. [https://doi.org/10.1016/S1096-7516\(00\)00016-6](https://doi.org/10.1016/S1096-7516(00)00016-6).
- Gross, D., Pietri, E. S., Anderson, G., Moyano-Camihort, K., & Graham, M. J. (2015). Increased preclass preparation underlies student outcome improvement in the flipped classroom. *CBE Life Sciences Education*, 14(4), 1–8. <https://doi.org/10.1187/cbe.15-02-0040>.
- Guo, P. J., Kim, J., & Rubin, R. (2014). How video production affects student engagement: An empirical study of MOOC videos. *Proceedings of the first ACM conference on Learning@scale* (pp. 41–50): ACM.
- Hao, Y. (2016). Exploring undergraduates' perspectives and flipped learning readiness in their flipped classrooms. *Computers in Human Behavior*, 59(1), 82–92. <https://doi.org/10.1016/j.chb.2016.01.032>.
- Herreid, C., & Schiller, N. (2013). Case studies and the flipped classroom. *Journal of College Science Teaching*, 42(5), 62–66.
- Johnson, G. M. (2005). Student alienation, academic achievement, and WebCT use. *Educational Technology & Society*, 8(2), 179–189.
- Kim, M. K., Kim, S. M., Khera, O., & Getman, J. (2014). The experience of three flipped classrooms in an urban university: An exploration of design principles. *The Internet and Higher Education*, 22(1), 37–50.
- Lape, N., Levy, R., & Yong, D. (2015). Probing the inverted classroom: A study of teaching and learning outcomes in engineering and mathematics. *SEI Case Study Series, EDUCAUSE Learning Initiative* (pp. 1–5).
- Lazonder, A. W., & Harmsen, R. (2016). Meta-analysis of inquiry-based learning. *Review of Educational Research*, 86(3), 681–718. <https://doi.org/10.3102/0034654315627366>.
- Lee, M. K., Cheung, C. M., & Chen, Z. (2005). Acceptance of Internet-based learning medium: The role of extrinsic and intrinsic motivation. *Information Management*, 42(8), 1095–1104. <https://doi.org/10.1016/j.im.2003.10.007>.
- Long, T., Logan, J., & Waugh, M. (2016). Students' perceptions of the value of using videos as a pre-class learning experience in the flipped classroom. *Tech Trends*, 60(3), 245–252.
- Owens, D. C., Sadler, T. D., Barlow, A. T., & Smith-Walters, C. (2017). Student motivation from and resistance to active learning rooted in essential science practices. *Research in Science Education*. <https://doi.org/10.1007/s11165-017-9688-1>.
- Ryan, M. D., & Reid, S. A. (2016). Impact of the flipped classroom on student performance and retention: A parallel controlled study in General Chemistry. *Journal of Chemical Education*, 93(1), 13–23. <https://doi.org/10.1021/acs.jchemed.5b00717>.
- Sankaran, S. R., Sankaran, D., & Bui, T. X. (2000). Effect of student attitude to course format on learning performance: An empirical study in Web vs. lecture instruction. *Journal of Instructional Psychology*, 27(1), 66–73.
- Smith, J. D. (2013). Student attitudes toward flipping the general chemistry classroom. *Chemistry Education Research and Practice*, 14(4), 607–614. <https://doi.org/10.1039/C3RP00083D>
- Tawfik, A. A., & Lilly, C. (2015). Using a flipped classroom approach to support problem-based learning. *Technology, Knowledge and Learning*, 20(3), 299–315. <https://doi.org/10.1007/s10758-015-9262-8>.