Online Engagement in an Undergraduate Cell Biology Course

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Online engagement, or the use of online supplementary instruction and assessment, in high-structure courses is gaining popularity as a useful tool to facilitate instruction, assignments, and examinations. High-structure courses, which include regular pre- and post-class assessments and significant active learning during class, have been shown to increase student engagement and improve student performance, whereas electronic learning has shown mixed results. The goal of this study was to assess online engagement in a large-enrollment, lecture-style undergraduate cell biology course. The course was taught using a high-structure approach that required students to read the textbook and complete assignments before class, actively participate in class, complete review quizzes after class, and assess learning through examinations. Use of the online component was voluntary and included the e-book, associated online guides, videos, hyperlinks, experimental walk-throughs, and enhanced practice questions not found in the textbook. We found that while a statistically significant difference on preclass assignments resulted from voluntary use of the online component, no difference was observed on examinations. Satisfaction or future-use scores did not stratify along preclass assignments or examinations. Future studies are needed to define how to successfully incorporate online engagement in high-structure large lecture courses.

The modernization of STEM (science, technology, engineering, and math) education has led to an increasing number of calls to improve undergraduate teaching in STEM fields. Motivation for change is high at all levels, from national commissions to individual researchers (Henderson et al., 2011), to implement fundamental change of the undergraduate education experience and shift the focus from instructor-centered to student-centered education (Barr & Tagg, 1995). While these calls are broad and address all STEM disciplines, *Vision and Change in Undergraduate Biology* (American Association for the Advancement of Science, 2011) suggests the implementation of student-centered education in the life sciences. Incorporating electronic or online supplemental learning (e-learning) to high-structure and active learning courses, which are discussed in more depth later, is a popular way to provide student-centered classroom instruction.

Science is commonly taught through lectures and textbooks. Although this approach may be effective for certain students, it may also contribute to students leaving the sciences (Handelsman et al., 2007). High-structure courses help stem the exodus of students away from the sciences, improve student exam scores, and reduce failure rates (Freeman et al., 2011). High-structure courses are defined as those that include (1) one or more weekly graded assignments due before class, (2) significant amounts of active learning during class, and (3) one or more weekly graded review quizzes due after class (Eddy & Hogan, 2014). High-structure teaching and active learning, defined as the significant use of interactive questions and group discussions during class, also reduce the achievement gap between students and improve understanding of concepts, attendance, engagement, and satisfaction in STEM courses (Armbruster et al., 2009; Deslauriers & Wieman, 2011; Haak et al., 2011; Knight & Wood, 2005; Prince, 2004). For example, in a large-scale meta-analysis of traditional (defined as lecture-based instruction) and active learning courses, average examination scores improved by approximately 6% in active learning sections, whereas students exposed to traditional lecturing sections were 1.5 times more likely to fail (Freeman et al., 2014).

E-learning can be useful as part of high-structure courses and can incorporate the use of the internet to facilitate reading assignments, preclass and postclass online quizzes, and online assignments. Courses that incorporate e-learning expose students to scientific concepts through an avenue that may be more familiar. How effective is e-learning? A systemic literature review revealed that in 12 studies, each of which compared the effectiveness of an online computer-aided e-learning group with that of a traditional learning group (lecture or seminar) conducted among dental students, 5 studies showed a significant advantage with e-learning students, while 6 showed no difference between e-learning and traditional students (Rosenberg et al., 2003), suggesting that e-learning is as effective as traditional learning. A subsequent analysis of dental students showed that e-learning in a blended course, which included both a traditional face-to-face lecture along with additional online learning components, significantly improved student scores and satisfaction compared to the traditional lecture setting (Kavadella et al., 2012). Another meta-analysis of nursing education revealed that online and blended e-learning resulted in significantly higher test scores than traditional learning (Voutilainen et al., 2017), a result that has been shown across STEM courses (Anderson & Krichbaum, 2017; U.S. Department of Education, 2010).

With technology and e-learning playing a greater role in the classroom, many publishers have begun developing online learning tools to supplement a traditional textbook. For example, Pearson's Mastering tool and Wiley's WileyPLUS online teaching and learning platform both incorporate an e-book with practice problems, visual set pieces, and links to other resources. Student perceptions of online activities are generally high and often result in higher subject scores (Freeman et al., 2007; Richards-Babb et al., 2015). However, few studies have looked at the effectiveness of a publisher-based resource as a learning tool. One recent study looked at the effectiveness of WileyPLUS for teaching differential equations in an undergraduate mathematics course (Silva et al., 2016). The study, which used a Likert-scale questionnaire, found that students thought WileyPLUS was an effective aid to instruction and students who used WileyPLUS achieved significantly better exam scores than students in the lecture-discussion control group. This suggests that publisher-based learning modules may be an effective e-learning supplement.

In most studies, multiple sections of the same course or the same course taught over time are used to compare the differences between e-learning and traditional learning. Although performance metrics are typically controlled by grade point average or SAT scores, inherent differences between sections or courses could alter performance. In this study, we analyzed the performance of students in a large cell biology lecture course in which the e-learning components were voluntary. We found that significant differences in scores on preclass quizzes for e-learning and traditional learning students do not translate to improved postclass quizzes or exams.

Materials and methods

Course design and overview

An upper-division cell biology course was designed and taught at a large, research-intensive, doctorate-granting university in the western United States. The course enrolled mostly biological sciences and public health sciences majors (Table 1) who intend to further their education in health or graduate professional careers. The course was taught using a high-structure and active learning approach in a 10-week quarter, during which students met for three 50-minute lecture sessions each week. Altogether, students had 27 hours of lecture over the 10-week quarter. A passing grade of C or better in a molecular biology lecture course was a prerequisite for enrolling in this cell biology course. The course was an elective and not required to graduate in any major.

Students were encouraged to sign up for the WileyPlus online system, which would allow them to access the e-book, associated online guides, videos, hyperlinks, experimental walk-throughs, and enhanced practice questions not found in the textbook. Students who did not elect to sign up for the WileyPlus online system used a traditional textbook for the course that had standard end-of-chapter

TABLE 1

Demographics of students enrolled in an undergraduate cell biology course.

Characteristics	Total (*n*)	Percentage
Total number of students	252	
Students who responded to survey	224	88.9
Gender		
Male	89	39.7
Female	135	60.3
Major		
Biological sciences	143*	63.8
Public health sciences	26	11.6
Human biology	16	7.1
Pharmaceutical sciences	9	4
Other	32*	14.3
Ethnicity		
White	36	16.1
Asian	143	63.8
Hispanic/Latino	41	18.3
African American	4	1.8
Average college GPA (± SD)	3.18 ± 0.47	

Note. SD = standard deviation.

questions. All students took the same preclass quiz online using either WileyPlus or Canvas, the default university-specific online learning management system that contains no textbook content. All students took an online weekly quiz using Canvas.

Lecture materials

The textbook used in the course was *Karp's Cell and Molecular Biology, Eighth Edition* (Karp et al., 2015). The online e-learning system WileyPlus was used to provide the e-book and associated online guides, videos, practice questions, and preclass quizzes. The lecture covered all major components and functions of the cell, excluding biochemistry and genetics. The topics included cell biology techniques, membranes, proteins, organelles, protein sorting, protein signaling, cell polarity, cell cycle, and cancer.

Lecture structure

The lecture was divided into three parts, all of which actively engaged students in the learning process (Table 2). In the preclass part, students were expected to read the assigned textbook chapters and complete a preclass quiz. The assigned reading was paired with learning objectives to orient the students, allowing them to focus their attention and take notes. The students had the option of using the online e-learning components associated with WileyPlus, which had online guides, videos, and practice questions, or of reading a physical textbook. After reading the textbook, they would complete an online, graded, multiple-choice preclass quiz either on WileyPlus or on Canvas. Students were only given one chance to get each question correct. There was one preclass assignment per day of class (27 total). The goal of the preclass part of the course was to have students begin to acquire basic content on their own and to give them an initial assessment on their learning. The preclass assignments were worth approximately 6% of the total course grade.

During the in-class part, students were expected to bring printouts or digital copies of the lecture slides to encourage note-taking during class. The lesson slides contained a list of learning objectives for the day that extended the learning objectives of the preclass reading assignment. During lecture, students would be exposed to a disease of the day that corresponded to the topic material, along with associated video or real-world scenarios. Students would also respond to a series of multiple-choice questions throughout the lecture using the iClicker classroom response system (software version 6.3), open-ended questions, and discussions with peers. An average 50-minute class contained approximately six active learning activities. Didactic lecture was used to enhance content not covered by the preclass reading assignment and to work through conceptual problems associated with the lecture topic. Students were given points for participating in, but not necessarily answering correctly, at least 50% of the day's iClicker questions. The goal of the in-class part of the course was to allow students to practice what they learned before class, to clarify misconceptions and ask questions, and to demonstrate their knowledge with applied and novel situations. In-class participation was worth approximately 5% of the total course grade.

In the postclass part, students were encouraged to review their notes after each lecture. Afterward, students would take an online, graded, multiple-choice weekly review quiz to assess their knowledge of the prior week's material (eight total quizzes, minus the weeks with midterm exams; quizzes taken on Canvas). Students were only given one chance to get each question correct. The goal of the postclass part of the course was for students to solidify and review each week's material and manage their studying prior to each exam. The weekly review quizzes were worth approximately 7% of the total course grade.

TABLE 2

Lecture structure for the undergraduate cell biology course.

Time frame	Lecture component
Before class	Reading guide (optional) Preclass quiz (graded)
During class	iClicker questions Lecture
After class	Studying (optional) Weekly review quiz (graded)

Summative assessments

Students were assessed throughout the course, with online preclass quizzes and online weekly quizzes as described in the previous section and written lecture examinations in which they were asked to demonstrate their knowledge by answering multiple-choice questions. The two midterm examinations covered the relevant preceding lecture material, and half of the final examination covered content from the entire course. The lecture examinations were worth approximately 80% of the total course grade.

Data collection

This study summarized data obtained from 224 total students. To be included in this study, students had to give their consent, complete all major summative assessments (preclass quizzes, weekly quizzes, and lecture examinations), and complete an online survey assessing their views on the use of the e-learning curriculum. Overall, 88.9% of students (224 out of 252) met these requirements (Table 1). Students were divided into traditional and e-learning groups based on their answers in a postcourse survey on which they indicated their past usage, satisfaction, and expected future use. This study was approved by the university's Institutional Review Board (HS# 2013-9959).

Data analysis and statistics

To determine what factors affected student performance in the course, average preclass quiz, weekly quiz, and lecture examination scores were estimated using multiple linear regression models with student demographic data (college grade point average [GPA], ethnicity, gender, and major). Multiple regression modeling was used to analyze the data because these models can control for student GPA. All quiz or examination scores are expressed as a percentage out of 100%.

To assess students' perceptions of the online course components related to their learning, students were asked to complete a postcourse survey on which they indicated their past usage, satisfaction, and expected future use. Students completed this survey during the last week of the course, and 0.5% of their course grade was based on the survey's completion.

We analyzed students' written comments to provide additional insight into their perceptions of the course. Anonymous student comments were obtained from both standard university end-of-course evaluations and a comprehensive tailored evaluation on the importance of each course component to their learning. All data were analyzed using Microsoft Excel version 16 and the statistical program R, version 3.1.2.

Results

The data from a cell biology course included in this study had 224 out of 252 students who were enrolled in this course, consented to being in the study, completed all summative assessments, and completed an online survey assessing their views on the use of the optional online e-learning curriculum. Demographic information is given in Table 1, which shows that female students, biological sciences majors, and Asian American students made up the majority of participants in this course.

Student demographics related to performance

To assess student demographics and their possible effect on performance, a multiple linear regression model was used to examine the relationships between average lecture examination scores and college

TABLE 3

Multiple linear regression analysis of the effects of the use of the online learning component on online preclass quiz performance.

Regression coefficient	Estimate ± SE	*p* value
Model intercept	60.13 ± 4.71	<2e-16***
Online learning component (yes)	7.16 ± 1.25	3.18e-08***
GPA	8.49 ± 1.33	1.16e-09***
Gender (male)	-0.12 ± 1.24	0.92
Ethnicity (African American)	-2.34 ± 4.78	0.62
Ethnicity (Hispanic)	1.77 ± 2.11	0.40
Ethnicity (Asian)	3.03 ± 1.70	0.08
Major (public health)	-7.78 ± 1.90	5.93e-05***
Major (other)	-3.45 ± 2.18	0.11

Note. The reference levels for this model are as follows: (1) did not use the online learning component, (2) female, (3) biological sciences major, and (4) Caucasian. This model included 224 students. SE = standard error.

***$p < 0.001$

TABLE 4

Multiple linear regression analysis of the effects of the use of the online learning component on examination performance.

Regression coefficient	Estimate ± SE	*p* value
Model intercept	-3.40 ± 4.72	0.47
Online learning component (yes)	-1.17 ± 1.25	0.35
GPA	21.18 ± 1.34	<2e-16***
Gender (male)	0.98 ± 1.24	0.43
Ethnicity (African American)	0.34 ± 4.79	0.94
Ethnicity (Hispanic)	0.36 ± 2.11	0.87
Ethnicity (Asian)	0.67 ± 1.70	0.69
Major (public health)	-7.07 ± 1.90	2.57e-04***
Major (other)	-0.43 ± 2.18	0.84

Note. The reference levels for this model are as follows: (1) did not use the online learning component, (2) female, (3) biological sciences major, and (4) Caucasian. This model included 224 students. SE = standard error.

***$p < 0.001$

GPA, ethnicity, gender, and major. No differences were found between genders (Tables 3 and 4). However, significant differences were found between majors, as performance by students with public health sciences majors was found to be lower than students in the other major categories (Tables 3 and 4).

We went on to assess whether use of an optional online e-learning system to supplement a high-structure active learning course would significantly alter student performance and found no differences between students who used or did not use the e-learning system when the class was evaluated as a whole, by gender lines, or by different ethnicities (Tables 3 and 4). We did find statistically significant differences from use of the e-learning system with students taking the preclass quiz (Table 3). The preclass quiz was generated using a subset of voluntary multiple-choice "concept check" questions found throughout each chapter in the online e-learning system, potentially giving an inherent advantage to students using the e-learning system. This advantage did not translate to lecture examinations (Table 4). We also did not see significant performance differences with students who previously used WileyPlus or another online e-learning system, nor significant differences in the number of online e-learning systems that students had used in the past. However, the results indicate that all students had some past experience using an online e-learning system from previous courses, which may have limited the differences between e-learning and traditional performance.

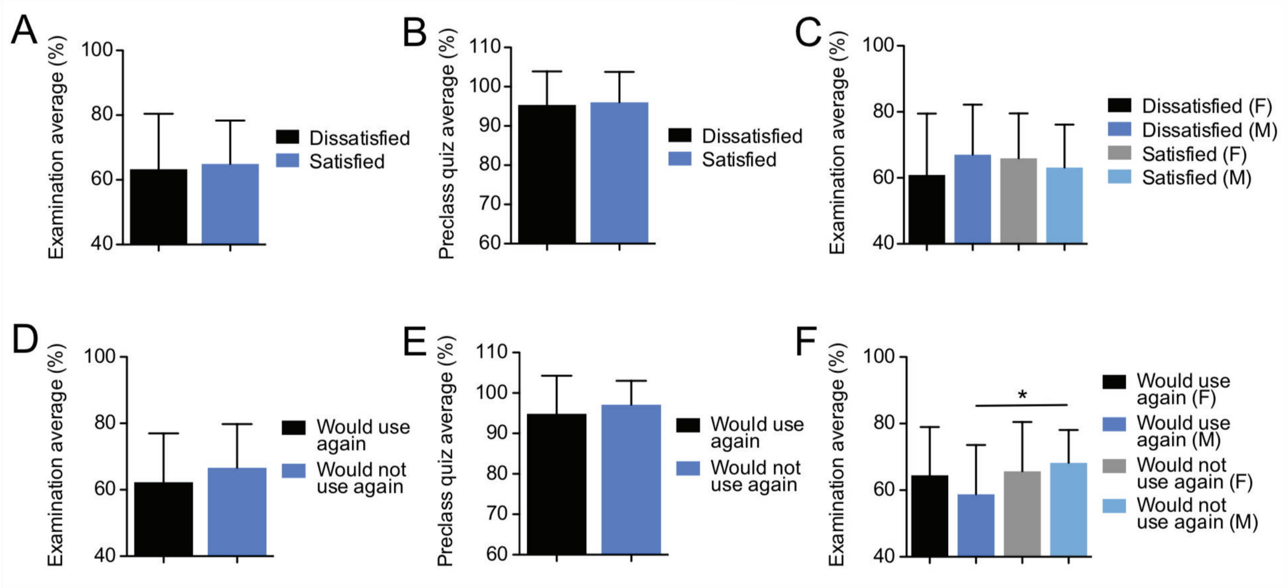
Students' evaluation of e-learning course components

At the end of the course, students were asked to evaluate the online e-learning course components in terms of past use, satisfaction, and future use. Of the 126 students who used the e-learning system and took the postcourse survey, there were no significant performance differences between students who were satisfied or dissatisfied with the e-learning system, nor were there any differences along gender lines (Figure 1A–C). Additionally, there were no significant performance differences between students who would use the e-learning system again versus those who would not (Figure 1D–E). There was a significant difference in the performance of male students, but not female students, with regard to those who would not use the e-learning system again (Figure 1F).

Students who chose to use Canvas, the online learning management system for quiz assessment, instead of the online e-learning system commented on the convenience and familiarity of the system and noted that "Canvas is

FIGURE 1

Student evaluations of the online learning components.



Notes. (A) Examination and (B) preclass quiz averages of students who used online learning components and responded with their satisfaction or dissatisfaction with the materials. (C) Examination averages and response regarding satisfaction stratified over male and female respondents. (D) Examination and (E) preclass quiz averages of students who used online learning components and responded whether or not they would use the online materials again. (F) Examination averages and response regarding future use stratified over male and female respondents. Error bars represent standard deviation; significance was determined by unpaired two-tailed *t* test (*, $p < 0.05$).

free." Other students felt that ebooks included in the online e-learning system were "difficult to read" and that the extra e-learning course materials provided by the e-learning system would not be helpful, partly because students did not have time in their schedules and partly because they lacked enthusiasm. For instance, one student commented, "I didn't think it would have been a good investment. Typically, I know that these platforms provide supplemental resources, but I never end up using them. Therefore, if it wasn't mandatory, I don't think it's something that I felt would be essential." In contrast, another student who did use the online e-learning system commented, "I wish I had more time to use all of them" in reference to the supplemental materials.

Discussion

Students enrolled in a high-structure cell biology course did not see significant improvement on postclass quizzes and exams when self-reporting the optional use of e-learning as part of their curriculum compared to students using a traditional textbook. While the reason for the lack of difference between students who used e-learning versus students who used traditional learning was not readily apparent from this study, there are several possibilities to explain the results. First, this study differs from other studies that show significant improvements in students who use e-learning (Silva et al., 2016) because the students in this study were in the same class and experienced the same lecture and activities. This finding may indicate subtle differences in lecture and instructor-student interactions between classes that may exaggerate the results between the experimental versus control groups. Second, the use of e-learning was optional, which may contribute to lower enthusiasm or commitment to use the e-learning activities within the e-learning cohort. Lower enthusiasm or commitment can contribute to lower program intensity or reduce the frequency of use of the e-learning activities. Although higher program intensity is an effective e-learning contributor, lower intensity (i.e., less than 30 minutes a week) provides small to insignificant effect sizes (Cheung & Slavin, 2013). Finally, this result may be unique to the students in this study, and a larger cohort may need to be studied over multiple years to observe differences between students who voluntarily use e-learning to supplement their education.

E-learning can be an effective part of high-structure courses, despite what our results indicate. For instance, in a meta-analysis of educational technology effectiveness for mathematics students, smaller cohorts of students on average produced larger effect sizes than larger cohorts of students (Cheung & Slavin, 2013), which suggests that having smaller class sizes or breaking up a large lecture course into smaller discussion groups may help increase the effectiveness of e-learning. This finding may point to the need for more support from instructors, peers, and information technology personnel to help students navigate and conceptually understand the e-learning materials (Noesgaard & Ørngreen, 2015). The amount of resources put into the e-learning materials is also an important factor. For instance, the more time the developer spends generating the e-learning content and the more time the student puts into e-learning materials, the greater the effectiveness of the e-learning activity (Cheung & Slavin, 2013). The increased time spent by the student on e-learning correlates with their competency in using the technology and allows for more practice with the technology, both of which can increase effectiveness of the online activity (Alinier et al., 2006). Finally, student motivation is an important factor and might be increased by tailoring the e-learning materials to a student's interests.

How could we alter our methods to increase student performance? One way would be to require the use of e-learning materials to increase buy-in with the technology and limit the perception that a student is doing more work than necessary. Guided peer feedback has been shown to increase the effectiveness of e-learning (Hwang et al., 2018) and can be incorporated into online assignments and readings. Eye-tracking studies in e-learning have shown some promise for how to design and implement effective online materials. For instance, placing related text and graphics in adjacent areas, using one verbal mode at a time, providing clear verbal explanations, and carefully explaining the goals and content of animations can help reduce extraneous cognitive load (Yang et al., 2018). Additionally, pre-training students with new e-learning environments can increase the effectiveness of those environments (Yang et al., 2018), suggesting that front-loading tutorials or adding more low-impact assignments may be worthwhile.

References

Alinier, G., Hunt, B., Gordon, R., & Harwood, C. (2006). Effectiveness of intermediate-fidelity simulation training technology in undergraduate nursing education. *Journal of Advanced Nursing*, *54*(3), 359–369.

American Association for the Advancement of Science. (2011). *Vision and change in undergraduate biology: A call to action.* American Association for the Advancement of Science. http://visionandchange.org/files/2011/03/Revised-Vision-and-Change-Final-Report.pdf

Anderson, L. C., & Krichbaum, K. E. (2017). Best practices for learning physiology: Combining classroom and online methods. *Advances in Physiological Education*, *41*(3), 383–389.

Armbruster, P., Patel, M., Johnson, E.,

& Weiss, M. (2009). Active learning and student-centered pedagogy improve student attitudes and performance in introductory biology. *CBE-Life Sciences Education*, *8*(3), 155–264.

Barr, R. B., & Tagg, J. (1995). From teaching to learning—A new paradigm for undergraduate education. *Change*, *27*(6) 13–23. https://doi.org/10.1080/00091383.1995.10544672

Chen, C.- H., Liu, J.- H., & Shou, W.- C. (2018). How competition in a game-based science learning environment influences students' learning achievement, flow experience, and learning behavioral patterns. *Educational Technology & Society*, *21*(2), 164–176. http://www.jstor.org/stable/26388392

Cheung, A. C. K., & Slavin, R. E. (2013). The effectiveness of educational technology applications for enhancing mathematics achievement in K–12 classrooms: A meta-analysis. *Educational Research Review*, *9*, 88–113. https://doi.org/10.1016/j.edurev.2013.01.001

Deslauriers, L., & Wieman, C. (2011). Improved learning in a large-enrollment physics class. *Science*, *332*(6031), 862–864. https://www.science.org/doi/10.1126/science.1201783

Eddy, S. L., & Hogan, K. A. (2014). Getting under the hood: How and for whom does increasing course structure work? *CBE-Life Sciences Education*, *13(3)*, 453–468. https://doi.org/10.1187/cbe.14-03-0050

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

Freeman, S., Haak, D., & Wenderoth, M. P. (2011). Increased course structure improves performance in introductory biology. *CBE-Life Sciences Education*, *10*(2), 175–186. https://doi.org/10.1187/cbe.10-08-0105

Freeman, S., O'Connor, E., Parks, J. W., Cunningham, M., Hurley, D., Haak, D., Dirks, C., & Wenderoth, M. P. (2007). Prescribed active learning increases performance in introductory biology. *CBE-Life Sciences Education*, *6*(2), 132–139. https://doi.org/10.1187/cbe.06-09-0194

Haak, D. C., HilleRisLambers, J., Pitre, E., & Freeman, S. (2011). Increased structure and active learning reduce the achievement gap in introductory biology. *Science*, *332*(6034), 1213–1216. https://www.science.org/doi/10.1126/science.1204820

Handelsman, J., Miller, S., & Pfund, C. (2007). *Scientific teaching.* W. H. Freeman and Company.

Henderson, C., Beach, A., & Finkelstein, N. (2011). Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature. *Journal of Research in Science Teaching*, *48*(8), 952–984. https://doi.org/10.1002/tea.20439

Hwang, G.- J., Tu, N.- T., & Wang, X.- M. (2018). Creating interactive e-books through learning by design: The impacts of guided peer-feedback on students' learning achievements and project outcomes in science courses. *Educational Technology & Society*, *21*(1), 25–36. https://www.jstor.org/stable/26273865

Karp, G., Iwasa, J., & Marshall, W. (2015). *Karp's cell and molecular biology: Concepts and experiments* (8th ed.). Wiley.

Kavadella, A., Tsiklakis, K., Vougiouklakis, G., & Lionarakis, A. (2012). Evaluation of a blended learning course for teaching oral radiology to undergraduate dental students. *European Journal of Dental Education*, *16*(1), e88–e95. https://doi.org/10.1111/j.1600-0579.2011.00680.x

Knight, J. K., & Wood, W. B. (2005). Teaching more by lecturing less. *Cell Biology Education*, *4*(4), 298–310. https://doi.org/10.1187/05-06-0082

Noesgaard, S. S., & Ørngreen, R. (2015). The effectiveness of e-learning: An explorative and integrative review of the definitions, methodologies and factors that promote e-learning effectiveness. *The Electronic Journal of e-Learning*, *13*(4), 278–290.

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, *93*(3), 223–231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

Richards-Babb, M., Curtis, R., Georgieva, Z., & Penn, J. H. (2015). Student perceptions of online homework use for formative assessment of learning in organic chemistry. *Journal of Chemical Education*, *92*(11), 1813–1819. https://doi.org/10.1021/acs.jchemed.5b00294

Rosenberg, H., Grad, H. A., & Matear, D. W. (2003). The effectiveness of computer-aided, self-instructional programs in dental education: A systematic review of the literature. *Journal of Dental Education*, *67*(5), 524–532. https://doi.org/10.1002/j.0022-0337.2003.67.5.tb03654.x

Silva, D. L., Sabino, L. D., Lanuza, D. M., Adina, E. M., & Lazaro, R. S. (2016). The effectiveness of the technology module (WileyPLUS) as learning management system tool in teaching differential equations. In S. I. Ao, L. Gelman, D. W. L. Hukins, A. Hunter, & A. M. Korunsky (Eds.), *Proceedings of the World Congress on Engineering, Vol. I* (pp. 78–83). Newswood. http://www.iaeng.org/publication/WCE2016/WCE2016_pp78-83.pdf

U.S. Department of Education, Office of Planning, Evaluation and Policy Development. (2010). *Evaluation of evidence based practices in online* *learning: A meta-analysis and review of online learning studies.* https://www2.ed.gov/rschstat/eval/tech/evidence-based-practices/finalreport.pdf

Voutilainen, A., Saaranen, T., & Sormunen, M. (2017). Conventional vs. e-learning in nursing education: A systematic review and meta-analysis. *Nurse Education Today*, *50*, 97–103. https://doi.org/10.1016/j.nedt.2016.12.020

Yang, F.- Y., Tsai, M.- J., Chiou, G.- L., Lee, S. W.- Y., Chang, C.- C., & Chen, L.- L. (2018). Instructional suggestions supporting science learning in digital environments based on a review of eye tracking studies. *Educational Technology & Society*, *21*(2), 28–45. https://www.jstor.org/stable/26388377

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