Evidence-Based Best Practices for Teaching STEM Classes Online

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Research suggests that online learning can equal face-to-face learning when designed and facilitated effectively (Means, 2010). Teaching online certainly requires some different approaches than the traditional F2F classroom, but many, perhaps *all* of the underlying principles of good teaching remain the same. And while it might feel untenable to teach STEM classes in the online environment, without the benefit of hands-on, 3-dimensional labs, there is a great deal of literature offering some evidence-based best practices and strategies for making those online classes valuable learning experiences.

PROVIDING CLEAR PATHS

- **Online navigation**

  Are your students adequately oriented to the online course environment? Do they *really* know or understand where to find everything or submit assignments? Sometimes simple navigation and logistics can be unanticipated stumbling blocks for students. (Pro tip: NEVER assume what students already know how to do!) Indeed, poor online course design and organization have been shown to diminish student motivation and satisfaction –important contributors to student retention in online courses (Boton & Gregory, 2015; Levy, 2007; Shea, Pickett, & Pelz, 2003).

  As such, to help students successfully navigate your online course, you might consider **providing a guiding document** with screen shots **or even a quick video** that offers directions to and explanations of course components, where to find things in the LMS, how to use other course technology, etc. in an easy-to-find place on the course homepage (Limmer, 2016; Freeman & Jarvie-Eggart, 2019). Also be sure to clarify technology requirements for the course: do they need access to a camera and microphone? Do they need to know how to use specific software? Etc. Furthermore, be sure to **utilize the "student view"** available in Canvas to confirm what students will actually see when they log in to the course. If there are items in the course menu that you are not using, take a few minutes to **clean up the course menu for students** so that they will only see what is necessary.

- **Course objectives and timeline**

  Just as when teaching a face-to-face course, it is equally paramount in an online course to identify and articulate **clear and measurable course learning outcomes** as well as provide a **clear timeline for course components** from the outset. Students understandably want to know what they can expect from the course, what is in turn expected of them, and when they are expected to turn things in – especially in courses such as Anatomy and Physiology that might be directly tied to their future career goals, and for the ambitious students who take those courses!

- **Progress through the course**

  Help students manage their time and avoid feeling overwhelmed by the entirety of the course by providing them with **weekly guides** either in written or video format. These guides might offer instructions for tackling each module, and overview of the learning objectives that will be addressed that week, invitations to connect via virtual office hours, and reminders about assignment deadlines or expectations and participation requirements.

COMMUNICATING WITH STUDENTS FREQUENTLY AND CLEARLY

- **Clear, consistent, concise, and tone-appropriate communication**

  Effective faculty-student communication is vital in online education, given that it is the primary connection students

will have with an institution; *written* communication is particularly important as the online classroom doesn't offer the same kind of visual, vocal, or other non-verbal cues as the F2F classroom. In fact, poor communication has been shown to play a pivotal role in online student attrition (Betts, 2009). The literature notes that online STEM instructors should be clear, concise, and consistent in how they communicate with students (Chen et al, 2108). Further, instructors should be mindful of how students might interpret their written communications in the absence of traditional non-verbal or vocal cues that might otherwise convey tone; carefully consider word choice and syntax, and avoid the use of all-caps.

- **Reminders and frequent updates**
  Research has shown that one of the most highly demanded instructor practices in online teaching include sending reminders (Chen et al, 2108). Successful distance learning requires higher levels of self-discipline and self-direction as well as time management, and as such, it follows that students – especially those new to the online classroom – benefit from and appreciate frequent reminders from instructors about upcoming due dates, quizzes, readings, and online discussions.

- **Articulate a timeframe for responses and clarify preferred modes of communication**
  Since many online courses don't include include regular, synchronous class meetings, email or other forms of asynchronous messaging becomes the primary mode of communication between faculty and students. It is consequently important to be responsive to student inquiries, but to also respect your own boundaries and capacities as an instructor so that you don't spend all of your time fighting back a mountain of email! Therefore, instructors should determine set and maintain a reasonable timeframe for responses, and be sure to **notify (and frequently remind) students about that timeframe.**

- **Take advantage of communication tools in Canvas to streamline messaging**
  If the prospect of your personal inbox flooded with disorganized student messages causes anxiety, you might instead take advantage of the various communication tools within the Canvas LMS. The **Canvas Inbox** can function like email, allowing instructors to message individual students or the entire class easily; it also allows you to view student messages within the context of a specific section without having to rely on the students to provide that information. The **Announcements** function allows instructors to post important messages to the entire class on the main course page, so that they are easily noticed by students upon logging in. The **Gradebook Messaging** function allows you to provide feedback on specific student assignments (written or even recorded) quickly and easily. Finally, the **Q & A Forum** in Canvas provides a centralized location to provide answers to common student inquiries; be sure to refer students to this frequently, or even announce when you have posted an important response.

ESTABLISHING A POSITIVE ONLINE "PRESENCE" AND HUMAN CONNECTION WITH STUDENTS

Research has consistently shown that a strong sense of instructor presence, along with frequent and meaningful faculty-student interactions improve student persistence, satisfaction, and achievement in online courses (Boton & Gregory, 2015; Freeman and Jarvie-Eggart, 2019; Ladyshewsky, 2013; Richardson et al, 2016; Sandercock, 2014).

- **Log in to the course frequently, and ask students to do so as well**
  It may seem silly to include this reminder, but it is worth repeating that it is imperative to log in to your online courses frequently to monitor student activity – particularly if questions are being posted on a forum. In particular, it can be beneficial to **establish a routine**, and to **let students know how often and when** you will be logging onto the course, whether it is every day or every other day, so that they know what to expect. Similarly, **students should be encouraged to log in a certain number of days** each week as well to maintain steady progress and meet with success in the course. (Again, without regular class meetings, it can be easy for students to fall behind if they are not skilled at

self-directed time management and learning.)

- **Hold "virtual office hours" consistently each week, and invite students with purpose**
  There are many ways to hold virtual office hours for online students: you might simply tell your students you will be at your computer at certain times and thus available to respond quickly to emails, instant messages, or phone calls, or you could be available for students in a personal online "Zoom" room or other form of online conferencing, such as Google Hangouts. Indeed, use of synchronous chat functions in particular can help build a sense of community and continuity (Hickerson & Giglio, 2009; Li & Pitts, 2009; Schwier & Balbar, 2002). One important component of successful office hours to remember is to **schedule them in differing blocks of time** to ensure that they are accessible for a majority of students (Freeman and Jarvie-Eggart, 2019; Guerrero & Rod, 2013). Likewise, it can be useful to convey to students the very real benefits of attending office hours – namely, the positive correlation with course grades, general academic performance, and student satisfaction (Guerrero & Rod, 2013; Hickerson & Giglio, 2009; Lau, 2003; Sapp & Simon, 2005).

  Certainly, all students might not take advantage of these opportunities on their own (just as with traditional F2F office hours), so it can likewise be beneficial to **invite your students with purpose** to do so. In one study, 27% of students surveyed claimed that they did not take advantage of office hours because they simply forgot (Guerrero & Rod, 2013); as such, sending regular email reminders about office hours has been shown to increase attendance by 32% (Urban-Lurain & Weinshank, 2000). It is also recommended that instructors personally invite struggling students to meet during office hours or by appointment to boost the likelihood of their attendance (Guerrero & Rod, 2013).

- **Create individual touchpoints with students**
  Finding ways to **interact with students individually** can likewise enhance your online presence and build rapport and foster community with students (Farah, 2020). Sending individual emails and video messages, answering questions or providing clarification via phone calls, and providing personalized comments on documents are just a few of the ways an instructor can provide more personalized touchpoints.

- **Use photos and videos (and encourage students to do the same!)**
  Incorporating photos and videos to personalize written instructions or course content when possible can **help "put a face" on you as the instructor**, cultivating that human connection (Freeman & Jarvie-Eggart, 2019). Encouraging students to do the same can likewise build a stronger sense of community amongst the class as a whole, which has been shown to improve student performance and satisfaction, particularly in online courses (Vesely, Bloom, & Sherlock, 2007; Young & Bruce, 2011). For instance, at the start of the course, you might post a brief introductory video to share a bit about yourself with your students, and as an initial assignment, you might ask them to post similar videos or simply photos that reveal an interesting element of their personalities.

FOSTERING STUDENT ENGAGEMENT

A wealth of research confirms the efficacy and impact of active learning strategies in STEM courses (Aji & Khan, 2015; Allain, 2020; Chen et al, 2018; Freeman et al, 2014; Haak et al, 2011; McConnell, Steers, & Owens, 2003; Prince, 2004; Watkins & Mazur, 2013). Further, student engagement in online STEM courses is positively correlated with student learning and satisfaction (Chen et al, 2018; Hegeman, 2015; Tibi, 2018). Below are just a few proven options for active student engagement in your online courses, along with some tips for success.

- **Varied participation modalities**
  One guiding principle for effective student engagement in general is to offer a variety of types of participation opportunities (Brookfield, 2015). Participation in an online course might look slightly different than it does in a

traditional F2F course, but the concept is generally the same! Some forms might be more familiar online discussions in written format, or small breakout discussion groups, a collaborative document, or response videos, to name a few.

- **Structured online discussions**
  Online discussions are certainly a tried-and-true component of distance learning and can take on many different forms: asynchronous threaded discussions, synchronous chats, or even email threads, to name just a few. Instructors are encouraged to provide staggered deadlines throughout the week for asynchronous discussions, differentiating between original posts and responses to peers. Instructors should also be sure to provide clear guidelines for expectations, and even establish a clear late policy to ensure timely and appropriate discussion (Freeman & Jarvie-Eggart, 2019). Asking and modeling open-ended questions can likewise facilitate richer discussion.

- **Problem-based learning activities**
  Relating content to practical situations through case studies, scenarios, and real-world examples helps students connect meaningfully to the material and understand its relevance. They also positively impact critical thinking and participation, and deepened student understanding of the content (Dori, Tal, & Hasaushu, 2003; Klosterman & Sadler, 2010; Yadav et al, 2007).

- **Shared text annotations**
  Collaborative annotation tools such as Nb (http://nb.mit.edu/welcome), Perusall (https://perusall.com/) and eMargin (https://emargin.bcu.ac.uk/) offer ways for online students to highlight, annotate, and discuss specific segments of course text, foster critical thinking skills, and encourage deeper examination of technical readings and course materials (Freeman & Jarvie-Eggart, 2019; Kumar, 2015).

- **Guided note-taking**
  Daniel Limmer, Anatomy and Physiology educator and author of *EMT Review Plus* (Pearson, 2016) and others recommend providing online students with note-taking guides that require students to fill in blanks while working through course materials (Hegeman, 2015; Limmer, 2016). This practice not only compels students to engage actively with course content, but also helps them acquire important note-taking skills and create useful study tools.

- **Peer instruction and collaboration**
  A great deal of research supports the efficacy of providing students with opportunities to collaborate with each other in the learning process, particularly in the STEM classroom (Lasry, Mazur, & Watkins, 2008; Sithole et al, 2017; Vajravelu & Muhs, 2017; Watkins & Mazur, 2013). Peer instruction in particular has been shown to support improved conceptual learning and problem-solving abilities, help level-up students with less background knowledge, and decrease student attrition (Lasry, Mazur, & Watkins, 2008). A variety of options exist for creating these opportunities for online students, such as small problem-solving groups using Zoom breakout rooms during synchronous class meetings, or asynchronous group assignments involving case studies. Students could take turns serving as discussion leaders. You might even simply help facilitate the creation of student study groups.

- **Screen-sharing, video demonstrations and whiteboard tools**
  Utilizing available technology for demonstrations, problem-solving, and drawing diagrams in the online classroom can likewise help improve student learning, performance, and engagement while also contributing to online instructor presence (Freeman and Jarvie-Eggart, 2019; Hegeman. 2015). One caveat: be sure to keep videos short and/or interspersed with other teaching methods to maximize attention and engagement (Freeman and Jarvie-Eggart, 2019; Guo et al, 2014; Inman & Myers, 2018; Spunzar, Moulton, & Schacter, 2013).

EMPLOYING CONSISTENT AND TRANSPARENT ASSESSMENT METHODS

- **Transparent Assignment Design**
  Transparent Assignment Design is a proven approach to assessment that calls for instructors to **articulate an assignment's purpose, task, and criteria upfront** for students (Winkelmes, Boye, & Tapp, 2019). Clear expectations, like clear communication, are especially important in the online environment given the change in types of contact with students, and unclear expectations can be a frequent source of frustration for online students (Bork, & Rucks-Ahidiana, 2013; Sheridan & Kelly, 2010).

- **Rubrics**
  Using rubrics to delineate evaluation criteria and how those criteria are tied to grading have also been shown to precipitate improved comprehension, deeper learning, and better performance by students (Boye, 2020; Howell, 2011; Petkov & Petkova, 2006; Reddy & Andrade, 2010; Reitmeier, Svendsen & Vrchota, 2004; Wyss, Freedman, & Siebert, 2014). Rubrics can also reduce student anxiety by allowing students to plan their approach to an assignment and focus their efforts with purpose (Andrade & Du, 2005).

- **Relevant examples**
  Students also benefit from seeing **sample assignment responses or even real-world examples that are tied to assignments** (Chen et al, 2018; Osborn & Neill, 2005; Winkelmes, Boye, & Tapp, 2019). Such examples can help students gain a more complete understanding of what a successful response looks like, or what is expected in the discipline, which is especially important for new or unacculturated students.

- **Low-stakes assessments and formative feedback**
  Opportunities for students to practice the skills they will be asked to demonstrate in larger assessments, and to receive formative feedback on their progress are critical to learner success – especially in STEM courses (Chen et al, 2018; Osborn & Neill, 2005; Fellin & Medicus, 2015; Freeman & Jarvie-Eggart, 2019; Nicol & McFarlane-Dick, 2006; Sullivan, 2017). These opportunities might take the form of ungraded quizzes, quizzes that allow multiple attempts, submission of rough drafts, or feedback on homework problems. Such **feedback should be meaningful, frequent, and timely** so that students can adequately reap the benefits and improve where needed before higher-stakes assessments (Chen et al, 2018; Freeman & Jarvie-Eggart, 2019).

REFERENCES

Aji, C. A., & Khan, M. J. (2015). Virtual to reality: Teaching mathematics and aerospace concepts to undergraduates using unmanned aerial systems and flight simulation software. Journal of College Teaching & Learning, 12(4), 177–188.

Allain, R. (2020, March). Moving your classes online? Here's how to make it work. *Wired.* Retrieved from https://www.wired.com/story/how-to-make-online-learning-work/

Andrade, H. L., & Du, Y. (2005). Student perspectives on rubric-referenced assessment. *Educational and Counseling Psychology Faculty Scholarship*, 2.

Barrett, S. (2020, March 23). Coronavirus on campus: College students scramble to solve food insecurity and housing challenges. *CNBC*. Retrieved from https://www.cnbc.com/2020/03/23/coronavirus-on-campus-students-face-food-insecurity-housing-crunch.html.

Betts, K. (2009). Lost in translation: Importance of effective communication in online education. *Online Journal of Distance Learning Administration*, *12*(2).

Bork, R. J. H., & Rucks-Ahidiana, Z. (2013). Role ambiguity in online courses: An analysis of student and instructor expectations. Community College Research Center Working Paper No. 64.

Boton, E. C., & Gregory, S. (2015). Minimizing attrition in online degree courses. *Journal of Educators Online*, *12*(1). Retrieved from https://files.eric.ed.gov/fulltext/EJ1051044.pdf

Boye, A. (2020, in progress). Guiding learning and assessments through rubrics.

Brame, C. (2020). Teaching labs remotely. Vanderbilt University Center for Teaching. Retrieved from https://cft.vanderbilt.edu/2020/04/teaching-labs-remotely/.

Brewster, J. (2020, April 15). Poll: 38% of college students lost work because of Coronavirus. *Forbes.* Retrieved from https://www.forbes.com/sites/jackbrewster/2020/04/15/poll-38-of-college-students-lost-work-because-of-coronavirus/#7055ec645ec9

Brookfield, S. D. (2015). *The skillful teacher: On technique, trust, and responsiveness in the classroom*. John Wiley & Sons.

Brown, S. (2020, March 25). When Covid-19 closed colleges, many students lost jobs they needed. Now campuses scramble to support them. *The Chronicle of Higher Education*. Retrieved from https://www.chronicle.com/article/When-Covid-19-Closed-Colleges/248345

Chen, B., Bastedo, K., & Howard, W. (2018). Exploring Design Elements for Online STEM Courses: Active Learning, Engagement & Assessment Design. *Online Learning*, *22*(2), 59-75.

Dori, Y. J., Tal, R. T., & Tsaushu, M. (2003). Teaching biotechnology through case studies—can we improve higher order thinking skills of nonscience majors?. *Science Education*, *87*(6), 767-793.

Farah, K. (2020, March). 4 tips for teachers shifting to teaching online. *Edutopia.* Retrieved from https://www.edutopia.org/article/4-tips-supporting-learning-home.

Fellin, W., & Medicus, G. (2015). Multiple choice tests: More than a time saver for teachers. International Journal of Engineering Pedagogy. 5(3). Retrieved from http://onlinejournals.org/index.php/i-jep/article/view/4376

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. PNAS, 111(23), 8410–8415. Retrieved from http://doi.org/10.1073/pnas.1319030111

Freeman, T.M., & Jarvie-Eggart, M.E. (2019). Best practices in promoting faculty-student interaction in online STEM courses. *2019 ASEE Annual Conference & Exposition*.

Gasiewski, J. A., Eagan, M. K., Garcia, G. A., Hurtado, S., & Chang, M. J. (2012). From gatekeeping to engagement: A multicontextual, mixed method study of student academic engagement in introductory STEM courses. *Research in higher education*, *53*(2), 229-261.

Goines, S. (2020, March 30). Surviving Cornoavirus as a broke college student. *New York Times.* Retrieved from https://www.nytimes.com/2020/03/30/opinion/coronavirus-economy-graduates.html.

Guerrero, M., & Rod, A. B. (2013). Engaging in office hours: A study of student-faculty interaction and academic performance. *Journal of Political Science Education*, *9*(4), 403-416.

Guo, P. J., Kim, J., & Rubin, R. (2014, March). How video production affects student engagement: An empirical study of mooc videos. Proceedings of the first ACM conference on Learning@ scale conference, USA, 41–50. doi:10.1145/2556325.2566239

Haak, D. C., HilleRisLambers J., Pitre E., & Freeman, S. (2011). Increased structure and active learning reduce the achievement gap in introductory biology. Science 332, 1213. DOI: 10.1126/science.1204820

Hegeman, J. (2015). Using instructor-generated video lectures in online mathematics courses improves student learning. *Online Learning, 19*(3).

Hickerson, C. A. and Giglio, M. (2009). Instant messaging between students and faculty: a tool for increasing student-faculty interaction. *International Journal on E-Learning* 8(1): 71 – 88.

Howell, R. J. (2011). Exploring the impact of grading rubrics on academic performance: Findings from a quasi-experimental, pre-post evaluation. *Journal on Excellence in College Teaching*, *22*(2), 31-49.

Inman, J., & Myers, S. (2018). Now streaming: Strategies that improve video lectures. IDEA Paper# 68. *IDEA Center, Inc.* Retrieved from https://files.eric.ed.gov/fulltext/ED588350.pdf

Klosterman, M. L., & Sadler, T. D. (2010). Multi-level assessment of scientific content knowledge gains associated with socioscientific issues-based instruction. *International Journal of Science Education*, *32*(8), 1017-1043.

Kumar, H. S. (2015). Collaborative online annotation for active reading: Pedagogies, tools, and challenges. Presentation at the Blended Learning in the Liberal Arts Conference, Bryn Mawr College. May 21, 2015. Retrieved from https://repository.brynmawr.edu/blended_learning/2015/2015/27/

Ladyshewsky, R. (2103). Instructor presence in online courses and student satisfaction. *International Journal for the Scholarship of Teaching and Learning, 7*(1). 1-23. https://doi.org/10.20429/ijsotl.2013.070113 5.

Lasry, N., Mazur, E., & Watkins, J. (2008). Peer instruction: From Harvard to the two-year college. *American journal of Physics*, *76*(11), 1066-1069.

Lau, L. (2003). Institutional factors affecting student retention. *Education* 124(1): 126 – 136.

Levy, Y. (2007). Comparing dropouts and persistence in e-learning courses. *Computers & education*, *48*(2), 185-204.

Li, L. and Pitts, J.P. (2009). Does it really matter? Using virtual office hours to enhance student-faculty interaction. *Journal of Information Systems Education, 20*(2), 175-185.

Limmer, D. (2016) 10 tips for successful online anatomy and physiology instruction. *Paramedic Chief, Digital Edition*. Spring 2016.

Means, B., Toyama, Y., Murphy, R., Bakia, M., and Jones, K. (2010*). Evaluation of Evidence-Based Practices in Online Learning: A Meta-Analysis and Review of Online Learning Studies.* US Department of Education. Office of Planning, Evaluation, and Policy Development. Policy and Program Studies Service. ED-04-CO-0040

McConnell, D. A., Steer, D. N., & Owens, K. D. (2003). Assessment and active learning strategies for introductory geology courses. Journal of Geoscience Education, 51(2), 205–216. http://doi.org/10.5408/1089-9995-51.2.205

Nicol, D. J., & Macfarlane-Dick, D. (2006). Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. Studies in Higher Education, 31(2), 199– 218.

Nguyen, T. (2020, April 15). Why millions of college students and young adults won't get a stimulus check. *Vox.* Retrieved from https://www.vox.com/the-goods/2020/4/15/21222170/stimulus-checks-dependents-excluded

Osborn, L, and Neill, J. (2005). Performance assessment in online learning. 19th Annual Conference on Distance Teaching and Learning. University of Wisconsin, Madison.

Palloff, R. M. & Pratt, K. (2013). *Lessons from the Virtual Classroom* (2nd Ed). San Francisco, CA: Jossey-Bass.

Petkov, D., & Petkova, O. (2006). Development of scoring rubrics for IS projects as an assessment tool. *Issues in Informing Science & Information Technology*, *3*, 499 – 509.

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, 93(3), 223–231.

Reddy, Y. M., & Andrade, H. (2010). A review of rubric use in higher education. *Assessment & evaluation in higher education*, *35*(4), 435-448.

Reitmeier, C. A., Svendsen, L. K., & Vrchota, D. A. (2004). Improving oral communication skills of students in food science courses. *Journal of Food Science Education*, *3*(2), 15-20.

Richardson, J, Besser, E. Koehler, A. Lim, J. and Strait, M. (2016). Instructors' perceptions of instructor presence in online learning environments. *International Review of Research in Open and Distributed Learning*, 17(4). 82-104. https://files.eric.ed.gov/fulltext/EJ1108404.pdf 4.

Roper, A.R. (2007). How students develop online learning skills. *Educause Quarterly* (1), 62 – 65.

Rothschild, N. (2020, April 15). College students' future jobs take a big hit. *Axios.* Economy and Business. Retrieved from https://www.axios.com/college-students-summer-jobs-85205102-e7e9-401e-b92c-3fe05fd52de5.html

Sandercock, I. (2014). How important is instructor presence in an online course?" *TeachOnline - Resources for Teaching Online.* October 13, 2014. Retrieved from https://teachonline.asu.edu/2014/10/important-instructor-presence-online-course/

Sapp, D.A. and Simon,J. (2005). Comparing grades in online and face-to-face writing courses: Personal accountability and institutional commitment. *Computers and Composition* 22(4): 471 – 489.

Schwartz, L. (2020, March). What teachers in China have learned in the past month. *Edutopia*. Retrieved from https://www.edutopia.org/article/what-teachers-china-have-learned-past-month.

Schwier, R., and Balbar, S. (2002). The interplay of content and community in synchronous and asynchronous communication: virtual communication in a graduate seminar. *Canadian Journal of Learning and Technology*, 28(2).

Shea, P. J., Pickett, A. M., & Pelz, W. E. (2003). A follow-up investigation of "teaching presence" in the SUNY Learning Network. *Journal of Asynchronous Learning Networks*, *7*(2), 61-80.

Sheridan, K., & Kelly, M. A. (2010). The indicators of instructor presence that are important to students in online courses. *MERLOT Journal of Online Learning and Teaching*, *6*(4), 767-779.

Sithole, A., Chiyaka, E. T., McCarthy, P., Mupinga, D. M., Bucklein, B. K., & Kibirige, J. (2017). Student attraction, persistence and retention in STEM programs: Successes and continuing challenges. *Higher Education Studies, 7*(1), 46.

Szpunar, K. K., Moulton, S. T., & Schacter, D. L. (2013). Mind wandering and education: From the classroom to online learning. *Frontiers in Psychology, 4*(495).

Sullivan, S. (2017). How I moved my A & P course online. *McGraw Hill Higher Education*.

Tibi, M. (2018). Computer science students' attitudes towards the use of structured and unstructured discussion forums in fully online courses. *Online Learning, 22*(1).

Urban-Lurain, M. and Weinshank, D.J. (2000). “Attendance and Outcomes in a Large, Collaborative Learning, Performance Assessment Course.” Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans.

Vajravelu, K., & Muhs, T. (2016). Integration of digital technology and innovative strategies for learning and teaching large classes: A calculus case study. *International Journal of Research In Education and Science (IJRES), 2(*2), 379–395.

Vesely, P., Bloom, L., & Sherlock, J. (2007). Key elements of building online community: Comparing faculty and student perceptions. *MERLOT Journal of Online Learning and Teaching*, *3*(3), 234-246.

Watkins, J., & Mazur, E. (2013). Retaining students in science, technology, engineering, and mathematics (STEM) majors. *Journal of College Science Teaching*, *42*(5), 36-41.

Wiggins, G. “Seven Keys to Effective Feedback.” Educational Leadership. Vol 70., No. 1. pp. 10-16. 2012. Available: http://www.ascd.org/publications/educational-leadership/sept12/vol70/num01/Seven-Key s-to-Effective-Feedback.aspx

Winkelmes, M., Boye, A., & Tapp, S. (2019). *Transparent Design in Higher Education Teaching and Leadership: A Guide to Implementing the Transparency Framework Institution-Wide to Improve Learning and Retention*. Stylus Publishing, LLC.

Wyss, V. L., Freedman, D., & Siebert, C. J. (2014). The development of a discussion rubric for online courses: Standardizing expectations of graduate students in online scholarly discussions. *TechTrends*, *58*(2), 99-107.

Yadav, A., Lundeberg, M., DeSchryver, M., Dirkin, K., Schiller, N. A., Maier, K., & Herreid, C. F. (2007). Teaching science with case studies: A national survey of faculty perceptions of the benefits and challenges of using cases. *Journal of College Science Teaching*, *37*(1), 34.

Young, S., & Bruce, M. A. (2011). Classroom community and student engagement in online courses. *Journal of Online Learning and Teaching*, *7*(2), 219-230.