ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Paper ID #32233

Assessment of online learning in STEM writing intensive physics classes in a community college during COVID-19

Dr. sunil Dehipawala, City University of New York, Queensborough Community College

Sunil Dehipawala received his B.S. degree from University of Peradeniya in Sri Lanka and Ph.D from City University of New York. Currently, he is working as a faculty member at Queensborough Community College of CUNY.

Prof. Vazgen Shekoyan

Dr. Vazgen Shekoyan is a professor of physics and his experiences include pedagogy, CubeSat, etc.

Dr. Dimitrios S. Kokkinos, City University of New York, Queensborough Community College

Dr. Dimitrios Kokkinos is an Associate Professor of Physics at Queensborough Community College of CUNY since 2017. He Completed his Electrical Engineering degrees (BE, ME, PhD) at CUNY and undergraduate in Physics in Europe. He worked in industry for AT&T Bell Labs and Verizon Communications for 23 years as a telecommunications engineer specialized in fiber optical system research and development. He is teaching pre-Engineering Physics courses, conducts research in fiber sensors and mentors student research projects.

Dr. Rex Taibu

Dr. Rex Taibu has taught studio physics classes for several years. His teaching experience has shaped his research focus. Currently, Dr. Taibu is actively engaged in

1) promoting scientific inquiry attitudes in students through designing, implementing, and assessing innovative inquiry based physics labs.

2) conducting research regarding the role of language in conceptual understanding.

3) exploring cosmic rays (detection, data collection, and analysis).

Mr. George Tremberger Jr

George Tremberger serves as Lecturer in City University of New York Queensborough Community College Physics Department and his interests include pedagogy and astronomy.

Prof. Tak Cheung

Tak Cheung, Ph.D., professor of physics, teaches in CUNY Queensborough Community College. He also conducts research and mentors student research projects.

Assessment Rubric Example of online learning in STEM writing intensive physics class in a community college during COVID-19

CUNY Queensborough Community College Physics Department

Abstract

The online delivery of STEM writing intensive physics classes in a community college during COVID-19 has been a challenge in terms of preparation time and selection of materials. The City University of New York imposed a writing intensive requirement across the curriculum several years ago and Queensborough Community College accepted the implementation of that component in its STEM Physics classes. ABET asserted that "STEM graduates play a vital role in developing meaningful solutions to societal problems, such as the public health crisis we are currently facing" in their web page response to COVID-19. The adaptation of face-to-face instruction to online instruction is one of the most utilized yet challenging solutions to the COVID-19 lockdown. The face-to-face pedagogical strategy of "Ask questions the other person will enjoy answering" has been implemented on Blackboard using the interactive video learning approach featured in the Playposit application. The Playposit interactive technology was initiated as an NSF SBIR project, which achieved the NSF endorsement status as being 300% more effective when compared to the regular video viewing without using Playposit. Asynchronous delivery of course materials could be used for synchronous delivery, whereas the reverse application from a synchronous mode to an asynchronous mode would require design changes. The online delivery design includes a) the utilization of a numeric plug-in example in several scenarios described by words using interactive audio, b) the modification of numeric information to illustrate the deduction process in the application of physics principles, and c) the inclusion of daily experiences as physics examples to illustrate the evidence-based methodology in an induction process. The assessment evaluation of a student's learning capabilities would certainly include grading but grading alone would not be the sole basis of that assessment. The assessment scheme provides for improvement of student self-awareness in terms of the Three-Whys, namely, "Why am I learning this, Why do people care that I learn this, and Why should I care?" It also promotes lateral thinking in terms of alternative solutions and encourages prospection. The impact of artificial intelligence software in student learning and plagiarism are discussed.

Keywords

Asynchronous online delivery, Playposit interactive technology, lateral thinking

Introduction

The sudden COVID-19 lockdown posted a challenge to community college faculty in terms of preparation time and selection of materials. Just prior to the lockdown in New York City, a 2020 March Harvard Business Review discussed about the digital divide [1]. It states that the IT infrastructure and support staff ratio per faculty member in top private universities is much better

than public universities. A community college may not have the standard equipment in terms of digital bandwidth, digital storage, video technology, etc. to match the MOOC delivery platforms already installed in the R1 University settings. The Board of Trustees at University of ZZ imposed writing intensive requirement across the curriculum. Our Queensborough Community College accepts the implementation of the writing intensive component in the STEM Physics classes. The ABET COVID-19 web page asserted that "STEM graduates play a vital role in developing meaningful solutions to societal problems, such as the public health crisis we are currently facing" The transference of face-to-face instruction to online instruction is one of the most obvious solutions in the COVID-19 lockdown. The use of asynchronously delivered audios and videos to mimic the face-to-face setting and to meet the diverse community college student schedules was implemented.

During the COVID-19 lockdown, a community college instructor could have very limited resources such as having only a one-person video production crew from script writing to dissemination. Knowing physics as a memory in video viewing could be different from the understanding of physics. The Bloom's taxonomy pyramid has six layers, with understanding as the second layer which builds on the first layer of memorization [2]. The higher cognitive processes in application, analysis, evaluation, and creation would follow from the understanding described in the second pyramid layer. A 2014 report showed that the studied students appreciated the flexibility of completing activities online face-to-screen but preferred face-to-face discussion [3]. The face-to-face standard pedagogy of "Ask questions the other person will enjoy answering", discussed in a Harvard Business Review article [4], has been implemented in the face-to-screen remote learning. The implementation used the learning principle of interactive video to promote understanding and the higher cognitive processes in the Bloom pyramid taxonomy. The interactive video learning can be implemented in Blackboard using the Playposit technology. Playposit was initiated as an NSF SBIR project. At the end of the NSF sponsorship, the Playposit technology achieved the NSF endorsement status as being 300% more effective when compared to the regular video viewing without the Playposit implementation. A physics course usually has 3 parts, namely, a lecture component, a recitation component, and a lab component. There are 14 labs to highlight the corresponding 14 physics topics in lectures and recitations. For a specific physics topic, assessment on 'what was done in the past" would provide guideline on "what ought to be done in the next implementation".

Known facts and information prior to the COVID-19 lockdown

Asynchronous delivery of lecture and recitation materials could be used for synchronous delivery. However, the reverse application from a synchronous mode to an asynchronous mode would require design changes. The online delivery pedagogy includes the transformation of a numeric plug-in example into several scenarios described by words using the Playposit interactive technology.

Queensborough Community College in New York City has a diverse population in terms of student access to computer. A student could be sharing a computer with her/his high school siblings. The MP3 audio for repeated listening would deliver the first level of "knowing-memorizing" content in the Bloom's taxonomy, with less demand on computing power. The

Playposit interactive technology on MP3 media would provide an alternative implementation when a community college budget (or an individual faculty budget) could not purchase the feature of "MP4 video upload". A community college administration could set a policy that faculty members should upload videos on Youtube, and then the videos would not carry any advertisements in the Playposit environment.

There are multiple Youtube physics videos produced by video production crews from universities, NSF, NASA, PBS, etc. prior to the lockdown. The established Youtube videos have much better quality when compared to the videos produced by a one-person crew during a lockdown. The insertion of interactive questions/answers on the selected Youtube videos would be deemed acceptable for the asynchronous delivery of materials.

Information in the first few months of COVID-19 lockdown

A Berkeley professor in the department of education, Zachary Pardos, discussed about an opportunity for creating dramatic innovation [5]. The adaptive tutoring systems, such as McGraw Hill Alerks, Pearson Mastering Physics, and Carnegie Learning MATHia were cited. Pardos stated that "Students can be interacting with a technology that has the capacity to personalize instruction — a limited capacity, but more so than a video or textbook." For a community college setting, another interactive solution would be the use of the Open Stax free physics book with each student paying 32 dollars subscription fee to the Expert TA system.

A "Death of lecture" was debated by faculty members at the University of Nottingham during the lockdown and shared on Youtube [6]. A caution on the flipped class pedagogy was put forward with a citation on the 2019 MIT publication, which reported that the flipped class pedagogy had limited success for the studied students in West Point [7].

Implementation for Fall 2020 asynchronous delivery

The Playposit technology enables an instructor to insert questions inside a MP3 listening assignment or MP4 viewing assignment. A "learning bulb" with a name would be built in three stages. First, the media would need to be identified in the Playposit environment. The input of an URL address would do. Direct upload from a computer is possible after the purchase of the "direct upload from computer" feature by an individual faculty or college administration. A free Playposit version with limited student access per month is also available. Second, an instructor would start the media and add a question at a specific time or video frame. A student would be asked to provide an answer for continued listening or viewing. The Q/A feature is the interactive essence of the Playposit technology. For example, multiple-choice questions could be added along the uploaded soundtrack or video track. The answers must be highlighted by an instructor for Playposit to remember the scores. Third, the privacy setting would need to be set, the bulb would need to be saved, and the bulb deployment link would need to be copied for delivery to students.

There are two popular delivery formats, namely MP3 and MP4. The MP3 audio-only format without interactive Playposit could be used as a recitation tool for auditory learners using their smart phones. Even though recent research showed that instruction based on the meshing hypothesis of modality-specific learning (auditory, visual, or kinesthetic) still needs replicable statistical evidence, our implementation assumed that listening remains as a valuable learning method for most students during the COVID-19 lockdown [8, 9]. The worked-example video pedagogy has been reported to be very effective in a 2020 August ASEE publication [10]. In order to implement the ASEE worked-example video pedagogy and to fulfill the writing intensive requirement imposed by City University of New York Board of Trustee, we have utilized the followings. Namely, (1) the changing of input numeric information in several examples to illustrate the deduction method in applying physics principles, (2) the incorporation of daily experience as physics examples to illustrate the evidence-based methodology in the induction process, and (3) the transformation of a numeric plug-in example into several scenarios described by words using interactive audio technology.

On the one hand, students taking physics already had practiced the deduction reasoning in the pre-requisite math courses such that asynchronous delivery of the deduction reasoning in the physics numeric exercises would be straight forward. One the other hand, the evidence-based induction reasoning would require lots of physics examples from daily experience. In general, the telling of facts and information in the MP3 audio would be inferior to showing in the MP4 video. The pedagogy on how to show facts and information in the MP3 audio is an interesting topic. The Sherlock Holmes stories broadcasted by BBC Radio were "showing the characters" with audio scripts following the books by Doyle. A good author would let the readers draw their own conclusions instead of telling the readers directly. A sentence "Upon returning, he/she was wet from head to toes even with an umbrella" would enable the readers to infer the fact that it was raining heavily. Showing the consequence of "wet from head to toes even with an umbrella" rather than telling the cause of "heavy rain" explicitly would be a writing style in English. Therefore, an acceptable practice in physics pedagogy would be the use of an audio script which follows the words in a physics textbook and shows the effects with hints about the cause. The audio could be using the "text to MP3 voice" or instructor's own voice. The MP3 audio learning effectiveness could be questioned in a post assessment inquiry. The ad-libbing extension of a script (or talking based on a memorized script) would also enhance a MP4 video content. The mimicking of extemporaneous monologue in asynchronous delivery would be effective, especially for instructors lacking formal theatrical background.

The transformation of a numeric plug-in example into several scenarios described by words would facilitate one of the learning outcomes in terms of the writing intensive deliverables. The transformation would enable the induction reasoning process related to the concept of "probable". From an instructor's perspective, a description using words related to various scenarios would still be deductive reasoning because the calculus, algebra, arithmetic tools are at the mastery level embedded in memorization already. An application of linear approximation using deduction by a faculty would be able to resolve any "probable" issues arising from the induction reasoning concerning daily experience. From a student's perspective, the numeric skill at the mastery level embedded in memorization would free up working memory for the understanding of physics. The freeing of working memory to create scenarios with words would

further enrich the induction reasoning process. An example of an audio script to enrich the induction reasoning process is shown in Appendix A.

The content richness in MP4 videos (showing real experiments and PHET simulations) would rule out the use of MP3 audio for universities meeting their digital expenses. However, there is at least one case that MP3 would be the preferred media as far as we know. The centripetal acceleration for an inertial frame observer is a standard explanation in introductory physics. The inertia in rotation that causes "centrifugal pseudo force" shown in MP4 videos could be confusing for the understanding of physics, due to the innate trust in "seeing is believing". NASA posted a webpage explaining the centrifugal pseudo force, and the "inertia force" which lacks the additive property. The absence of additive property in the inertia force prevents any contributions to the net force in the Newton's second law of motion. Using the MP3 audio format to introduce phenomena in non-inertia rotating frames would free up more working memory for abstract reasoning. The freeing of working memory would be important for those students needing to divert working memory to refute "seeing is believing" in the viewing of the MP4 videos. Simply asking students to spin their bodies during walking would be easier to implement when equipped only with audio headsets, and the students would feel that their upper limbs fling out naturally [11].

Assessment Rubric Designs

Showing students how to do self-assessment is an important element in an assessment design, according to a 2017 ASEE publication [12]. Furthermore, the Gen Ed outcome assessment in terms of social learning could be included during the COVID-19 lockdown. A reflection usually can start with "Why". The 3-Whys: Why am I learning this? Why do people care that I learn this, and why should I care? are good starts for improving self-awareness. "Think About Your Own Thinking" is another deeper self-assessment metacognition strategy [13]. The auditory probabilistic thinking process in the induction reasoning upon the listening of MP3 media should be reflected in the students' answers [14]. Both formative and summative assessments are useful [15]. A weekly formative assessment may be able to grow a self-assessment mindset by the tenth week, and then a summative assessment at the fifteenth week would yield a holistic self-assessment in a COVID-19 lockdown semester.

The assessment of lateral thinking could be performed after teaching students on how to seek alternative solutions. Examples include the graphical solution method versus analytical method in kinematics, the energy method versus Newton's law of motion method, etc. Grading is an obvious quantitative measurement in this type of lateral thinking assessment with numeric information.

The assessment of the level of prospection could include an assessment of the prospective memory. For example, some students would forget to combine the x-component and y-component of the velocity for the final velocity vector with magnitude and direction when solving a projectile motion problem. It seems that the analytical solution of transforming a vector equation into scalar equations had already fully engaged their memory with little capacity for prospective memory. Whether bedtime stress would affect the next-day prospective memory performance is an important question [16]. Another assessment inclusion could be students'

creativity in terms of future simulation, the last layer in the Bloom's taxonomy pyramid. On the one hand, a pyramid construct would indicate the steps in the cognitive challenge during learning, with an analogy to the steps in the physical challenge during climbing. On the other hand, a pyramid construct with an ending vertex layer could be misleading because prospection, a future-oriented cognition, would provide positive feedback to the understanding described by the second pyramid layer. Another viewpoint would be "understanding starts at the second layer" without a pyramid construct. A 2014 PNAS report classified prospective cognition into four columns of simulation, prediction, intention, and planning, with two orthogonal rows of episodic and semantic processes [17]. Therefore, the prediction deliverable should be included in an assessment rubric. Furthermore, the ASEE Assessment-White-Paper stated that "program improvement is the objective of assessment and program modifications over relatively short intervals are likely to make assessment ineffective" [18]. The assessment rubric designs during asynchronous delivery should be blended into face-to-face instruction upon society reopen. An assessment rubric example is illustrated in Table 1.

Table 1: Assessment rubric example

Deliverable	Highly competent	Competent	Needs Improvement
The 3-Whys (25%)	Provided clear answer, showing self-awareness	Contained one mistake.	Contained two or more mistakes.
Lateral thinking 25%	Provided two correct alternatve solutions	Contained one mistake	Contained two or more mistakes
Episodic simulation construction (25%)	Constructed a simulation without any contradictions to physical laws	Contained one mistake	Contained two or more mistakes
Prediction (25%)	Provided a clear and correct probabilistic thinking process	Contained one mistake	Contained two or more mistakes

.

Discussion

The remote learning environment imposed by the COVID19 lockdown have limited the use of the assessment process developed in face-to-face classroom. For example, the Chegg.com website routinely posted questions submitted by students, and payments to Chegg.com would reveal the solutions. A list of multiple-choice questions could be on the Chegg.com website or any one of the tutoring websites when posted by a student. An assessment gain measure as a function of pre-score and post-score would be difficult to analyze given the added tutoring

uncertainty during the lockdown. An assessment based on a signal to noise (S/N) parameter instead of a gain measure could be used. A numeric example would illustrate the underlying principle. Let us assume that an assessment database has 100 multiple-choice questions, with 4 choices in each question. A student would receive a random selection of 10 questions, one point per question. A score of 5 out of 10 could be translated to an average success probability of 50%, which is the signal level (S) riding on a noise level (N) of 25%. An improvement of the S/N parameter from a midterm exam to a final exam could be computed with detailed noise modeling. The S/N parameter method does not require the pre and post to contain the exact questions. After society reopens, it would be an interesting project to compare the S/N parameter method with success probability to the gain measure method with uncertainty control.

Assessment and grading in asynchronous delivery mode would require the elimination of plagiarism. The use of AI software to convert "plagiarism content" to "plagiarism free" has been offered as a web service [19]. The new capability of AI software to write books would convey the idea of being educated and yet amoral [20]. According to OpenAI, their software products are so advanced that they need to prevent their products from being misused [21]. When the OpenAI software products stand the test of time in a year or two years, the AI software writing tool would generate various writing choices and could be used to consolidate the induction reasoning process through words. Plagiarism in a writing intensive physics class can be avoided when a student accepts that an AI software generated essay is only a draft for improvement upon reflection.

The COVID-19 induced remote learning may have positive implications. Professor Ishwar K. Puri, Dean of Engineering McMaster University, proposed 5 ways to harvest this remote learning experience for continued practice when reopen [22]. The most encouraging proposal must be the creation of a free virtue learning library in which every faculty member contributes modules with duration of 10 to 15 minutes. Eventually this library would free up faculty time to mentor challenged-based learning.

A lifelong goal of developing and retaining working memory capacity cannot be overlooked in an asynchronous delivery pedagogy of an engineering education. Working memory training benefits in math learning has been shown in 2018 [23]. A 2020 working-memory-task study showed that the EEG P3 signal was correlated to academic performance [24]. Recent studies on working memory capacity related to gray matter changes [25], single gene expression [26], and brain region synchrony [27] have been reported. These reports firmly support that the working memory capacity can be developed, at least in the training tasks, if not in overall fluid intelligence with transference. The strategy to develop working memory capacity in face-to-face instruction reported by us in a 2018 ASEE paper could be adapted for asynchronous deliver [28]. For instance, the cited examples of kinematics with algebraic complex numbers and collision with apparent mass using spring energy in face-to-face instruction can be converted to PPTX with audio for asynchronous delivery, given enough time for the conversion process.

Limitation

The Table 1 assessment rubric example lacks specificity and can be tailored for various learning topics in an assessment evaluation of asynchronous delivery. It would take several lockdown

semesters to collect enough data for comparison with face-to-face delivery. One can also argue that students at different ends of the performance spectrum would underrate or overrate themselves such that the self-assessment should be less than 25 percent in the rubric [12]. Despite these limitations, the present paper shares asynchronous delivery implementation and assessment rubric solutions in meeting the needs of our community college physics learning students during lockdown in New York City.

Conclusions

The present paper described an asynchronous online delivery of remote introductory physics lectures in a community college during COVID-19 lockdown in New York City. The implementation emphasizing self-awareness and lateral thinking had benefitted from the use of interactive audio and video in the learning process, with an implementation of the Playposit technology endorsed by NSF. An assessment rubric example was developed with guidance from assessment rubric examples in the literature published prior to the COVID-19 lockdown.

Acknowledgments

The authors thank Mr. Alexei Kisselev of CUNY-QCC for computer support. The authors thanks Dr. Eric Cheung of Montefiore Mount Vernon Hospital for discussion on neuroscience. The authors thank instructors sharing their videos on the open web. The authors thank the three anonymous reviewers of the 2020 Fall ASEE Mid-Atlantic Conference hosted by Stevens Institute of Technology.

Appendix- A

AMP3 interactive question, illustrated by […] can be inserted when inside the Playposit setting.

An audio script example
In Lesson 1 the oscillation period is governed by the square root of mass divided by the spring constant. Mass is simply the parameter associated with velocity squared kinetic energy and spring constant is associated with the displacement squared potential energy. In the associated differential equation, the period is inside the sinusoidal term. In Lesson 2, the pendulum oscillator period depends on the environment, that is, gravitational potential effect of the mass interaction with a planet, which is the 9.8 meter per second per second acceleration for Earth; and the length of the pendulum related to the moment of inertia kinetic effect. The potential energy mass cancels kinetic energy mass so the pendulum period depends on geometry length and the gravitational acceleration of the environment [question on the conical pendulum situation in which the 2*pi factor in the period formula is explicit without a differential equation]. In Lesson 3, a collection of spring-mass local oscillators enables a global

collaboration such that local oscillators have specific spatial temporal relationship to each other; given an applied y axis pulse [question on water surface ripples similarity with a violin excited by its bow]. With the spatially separated oscillators jumping up and down at specific time delays, the spatial temporal relationship results in a sequential timing pattern of the oscillators along the spatial x axis. The information flowing along the x spatial axis for oscillators to jump one by one in sequential order is enabled by oscillator coupling, called tension in the case of string. The coupling supports a global movement of energy called wave propagation with velocity related to the coupling tension. Upon reflection at a boundary, interference effects can be set up to obtain a standing wave pattern with trapped energy between the left and right boundaries. Each string oscillation element would have equal energy, although the kinetic energy and potential energy would vary for different string elements. Large amplitude string element has more tension for potential energy, while large kinetic energy string element has less tension carrying less potential energy.

References

1 Vijay Govindarajan and Anup Srivastava. What the Shift to Virtual Learning Could Mean for the Future of Higher Ed. Harvard Business Review March 31 2020. https://hbr.org/2020/03/what-the-shift-to-virtual-learning-could-mean-for-the-future-of-higher-ed

2 C.J. Brane "Flipping the Classroom", Vanderbilt University Center for Teaching, 2013 (Retrieved Sep 16 2020) Flipping the Class. https://cft.vanderbilt.edu/guides-sub-pages/flipping-the-classroom/

3 Nenagh Kemp and Rachel Grieve. Face-to-face or face-to-screen? Undergraduates' opinions and test performance in classroom vs. online learning. Front Psychol. 2014 Nov 12;5 :1278. https://pubmed.ncbi.nlm.nih.gov/25429276/

4 Alison Wood Brooks and Leslie K. John. The Surprising Power of Questions. Harvard Business Review May–June 2018 issue (pp.60–67). https://hbr.org/2018/05/the-surprising-power-of-questions

5 Berkeley News 2020. Last accessed Sep 20, 2020. https://news.berkeley.edu/2020/05/27/the-pandemic-could-open-a-door-to-new-technology-and-dramatic-innovation-in-education/

6 Death of The Lecture - Sixty Symbols University of Nottingham, Jul 28, 2020. https://www.youtube.com/watch?v=vv1134PLylU

7 MIT. Flipping great? The case for and against flipping the classroom. 2019. http://seii.mit.edu/research/study/effects-of-the-flipped-classroom-evidence-from-a-randomized-trial/ http://seii.mit.edu/wp-content/uploads/2019/08/SEII-Discussion-Paper-2019.07-Setren.pdf

8 Karoline Aslaksen, Håvard Lorås. The Modality-Specific Learning Style Hypothesis: A Mini-Review. Front Psychol. 2018 Aug 21; 9:1538. https://pubmed.ncbi.nlm.nih.gov/30186209/
9 Beth A Rogowsky, Barbara M Calhoun, Paula Tallal. Providing Instruction Based on Students' Learning Style Preferences Does Not Improve Learning 2020. Front Psychol. 2020 Feb 14; 11:164. https://pubmed.ncbi.nlm.nih.gov/32116958/
10 Sarah Dart, Edmund Pickering, Les Dawes. Worked Example Videos for Blended Learning in Undergraduate Engineering. Advances in Engineering Education. Summer 2020 Volume 8 Issue 2 https://advances.asee.org/wp-content/uploads/vol08/issue02/Papers/AEE-27-Dart.pdf
11 NASA. Frames of Reference: The Centrifugal force. 2006 https://pwg.gsfc.nasa.gov/stargaze/Sframes3.htm
12 ASEE self-assessment. Do students at different ends of the performance spectrum underrate or overrate themselves? Self-Assessment to Improve Learning and Evaluation. https://www.asee.org/public/conferences/78/papers/19411/view
13 Saga Briggs. Learning to Ask Better Questions: 12 Tricks. The Open College Australia 2015. Last accessed Sep 20 2020. https://www.opencolleges.edu.au/informed/features/learning-to-ask-better-questions-25-tricks/
14 Hannah J Stewart, Jasmin L Martinez, Audrey Perdew, C Shawn Green, David R Moore. Auditory cognition and perception of action video game players. Sci Rep 2020 Sep 1;10(1):14410. https://pubmed.ncbi.nlm.nih.gov/32873819/
15 Formative v. Summative assessment. Vanderbilt University. Last accessed Sep 20, 2020. https://www.vanderbilt.edu/pie/types-of-assessment/
16 Zoë-Lee Goldberg, Kevin G F Thomas, Gosia Lipinska. Bedtime Stress Increases Sleep Latency and Impairs Next-Day Prospective Memory Performance. Front Neurosci. 2020 Jul 28;14: 756. https://pubmed.ncbi.nlm.nih.gov/32848547/
17 Karl K Szpunar, R Nathan Spreng, Daniel L Schacter. A taxonomy of prospection: introducing an organizational framework for future-oriented cognition. Proc Natl Acad Sci U S A. 2014 Dec 30;111(52):18414-21. https://pubmed.ncbi.nlm.nih.gov/25416592/
18 ASEE White paper https://www.asee.org/papers-and-publications/Assessment-White-Paper-1.pdf
19 https://www.plagiarism-remover.com
20 Jules Bonnard. Tech Xplore. Educated yet amoral: AI capable of writing books sparks awe. Sep 2 2020. https://techxplore.com/news/2020-09-amoral-ai-capable-awe.html
21 OpenAI. Discovering and enacting the path to safe artificial general intelligence. Last accessed Sep 28 2020. https://openai.com/
22 Ishwar K. Puri. 5 ways university education is being reimagined in response to COVID-19. August 25 2020. https://theconversation.com/5-ways-university-education-is-being-reimagined-in-response-to-covid-19-144052
23 Hongxia Zhang, Lei Chang, Xiaoying Chen, Liang Ma, Renlai Zhou. Working Memory Updating Training Improves Mathematics Performance in Middle School Students With Learning Difficulties. Front Hum Neurosci. 2018 Apr 24; 12:154. https://pubmed.ncbi.nlm.nih.gov/29740298/

24 Wei Luo, Renlai Zhou. Can Working Memory Task-Related EEG Biomarkers Measure Fluid Intelligence and Predict Academic Achievement in Healthy Children? Front Behav Neurosci. 2020 Jan 22; 14:2. https://pubmed.ncbi.nlm.nih.gov/32038192/

25 Maro G Machizawa, Jon Driver, Takeo Watanabe. Gray Matter Volume in Different Cortical Structures Dissociably Relates to Individual Differences in Capacity and Precision of Visual Working Memory. Cereb Cortex. 2020 Jul 30;30(9):4759-4770. https://pubmed.ncbi.nlm.nih.gov/32396203/

26 Veronica C Galvin, Sheng Tao Yang, Constantinos D Paspalas, et al. Muscarinic M1 Receptors Modulate Working Memory Performance and Activity via KCNQ Potassium Channels in the Primate Prefrontal Cortex. Neuron. 2020 May 20;106(4):649-661.e4. https://pubmed.ncbi.nlm.nih.gov/32197063/

27 Kuangfu Hsiao, Chelsea Noble, Wendy Pitman, et al. A Thalamic Orphan Receptor Drives Variability in Short-Term Memory. Cell. 2020 Sep 29; S0092-8674(20)31152-1. https://pubmed.ncbi.nlm.nih.gov/32997977/

28 Vazgen Shekoyan, Sunil Dehipawala, George Tremberger, Raul Armendariz, David Lieberman and Tak Cheung (2018, April), Improving critical thinking through the cognitive loading control of working memory in introductory physics classes. Paper presented at 2018 ASEE Mid-Atlantic Section Spring Conference, Washington, District of Columbia. https://peer.asee.org/29465