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Teaching Tips To Enrich Remote Student Engagement in Transport Phenomena Using a Hybrid Teaching and Assessment Model

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Abstract—The pandemic-induced transition to remote instruction provided uniqueopportunities to adapt active and problem-based learning principles to develop newmaterials, teaching strategies, and assessment metrics that enrich studentengagement in transport phenomena. This project used a hybrid teaching strategy that delivered technical contentusing, both, alternate asynchronous podcasts and synchronous online sessions.Assessment was performed using remote mini-assignments every week thatchallenged student technical comprehension and development of problem-solvingalgorithms. Short assignments were administered via timed internet sharing anddiscussed synchronously immediately after online submission. Student performance on mini-assignments steadily increased and was 15%higher during remote instruction than the previous year of in person lectures. Inaddition, virtual class participation in office hours increased by 40% and class timespent on student-initiated questions was 34% higher during online sessions. A hybrid teaching and assessment strategy promoted problem-basedlearning to dramatically increase student engagement and performance online. Futurecurricula will continue to provide recorded solutions to complex problems to helpincrease student comprehension and class participation. In addition, virtual office hourswill be expanded in conjunction with faculty colleagues to provide additional resourcesto students.

Keywords—Problem-based learning, Non-traditional undergraduates, Growth mindset, Online upload.

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CHALLENGE STATEMENT

The 2020 pandemic initiated an immediate and transformative shift to remote instruction for many educational institutions. Engineering courses faced unique assessment challenges in this abrupt transition, as our discipline relies upon analytical rigor coupled with practical application. Transport phenomena is a cornerstone of many Biomedical Engineering (BME) undergraduate curricula that introduces students to fundamental concepts of fluid mechanics, thermodynamics, mass transfer, and heat transfer, sometimes for the first time. Moreover, contemporary transport curricula have included engineering frameworks for problem-solving to enrich student development and career preparation, which rely upon peer interactions in group settings such as small group exercises or in class discussion of open-ended problems.[1,2] A principal challenge in the remote instruction of transport is upholding class engagement in BME application while developing accurate assessment of essential analytical skills.

While engineering students are traditionally assessed using take-home assignments and questions, remote authenticity is now challenged by abundant opportunities for plagiarism via social media, online forums, and a student culture that accepts increasing levels of academic dishonesty.[3] To further detriment, increased opportunities for plagiarism have diminished the traditional effectiveness of remote assessments in helping instructors pace the difficulty level of the course or introduce new concepts and applications. The current brief describes a hybrid teaching and assessment strategy adopted for remote instruction in a

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required course of transport phenomena with an enrollment of 55–60 BME undergraduates. Remote instruction used a hybrid instructional model that delivered, both, asynchronous podcasts of technical material and synchronous online lectures of engineering application during the second half of the 2020 semester.

NOVEL INITIATIVE

Initial Practices

In person instruction relied upon 2.5 contact lecture hours per week and 3 exams of 90-min length for assessment. During the initial transition to remote instruction, we sought to uphold the syllabus and course structure by using synchronous lectures (e.g., webex, zoom) and exam proctor software with live webcam feeds. However, data gathered via student survey illustrated that requirements of livestream webcams and specialized software disproportionately impacted students with smaller and shared living spaces (38% of class), homes with multiple online learners (66%), or those using shared and older computers (27%).To alleviate these disparities, remote instruction was restructured as a hybrid teaching model that delivered content using asynchronous podcasts and 1.5 h of online synchronous lectures in a two to one ratio, as shown in Fig. 1. Moreover, the restructured model organized course materials into smaller modules and performed student assessment using remote assignments reviewed each class period.

Hybrid Assessments

Three traditional modules of transport fluid mechanics (physical properties, mathematics review, hydrostatics and pressure, mass conservation, inviscid and viscous flows), heat transfer (thermodynamic phase, conduction, convection, heat exchange), and mass transfer (solutes, solvents, diffusion, chemical equilibrium) were replaced with 9 smaller modules comprised of 2 asynchronous podcasts and one synchronous lecture, each. Office hours were also rescheduled to provide instructor availability after each a/synchronous session rather than the conventional once per week. Assessment was performed using a series of timed, mini-assignments administered and discussed online.

Asynchronous Component

Podcasts introduced new technical material remotely via website link (Canvas learning management systems (LMS), BigBlueButton.org) for a maximum of 30 min. Each asynchronous podcast contained a video recording of instructor-narrated content shown via presentation slides (Microsoft Powerpoint with timed animation). Podcasts were immediately available for download or live stream and PDF documents of the content presented were uploaded as supplements. Each podcast introduced new technical concepts using equations, figures, and references to the course textbook. Equations were derived following the mathematical frameworks of the text, while the physical meaning of each parameter was discussed alongside its units, range, and common values in engineering. An industry or research application was then introduced to help students formulate problem-solving algorithms. Here, line by line solutions were presented highlighting physical justifications for each step, selection of appropriate engineering parameters, importance of consistent units, and numerical values and calculations, as applicable. Smaller bonus questions were interwoven within the discussion to illustrate how different physical assumptions and boundary conditions can revise or modify the solution algorithm. The end of each podcast reviewed key points of the concepts presented and related the material to forthcoming modules. Important administrative confirmation of forthcoming steps, due dates, and topics was also provided.

Synchronous Component

The lecture period following every two podcasts was structured as a synchronous online session with three discrete sections. (1) *Assignment*: The first portion administered either a 15-min homework or a 30-min mini-exam via course website (Canvas LMS). Assignments were made available only through website view during the specified period and required answer upload within the allotted time. The assessment was entirely remote, sans proctor software or webcams, and very low-tech in that students uploaded images of each handwritten page via cell phone camera. Homework assessed student technical understanding using four multiple choice questions that reviewed the analytical concepts described via podcast. Mini-exams challenged students with one technical problem that assessed development of problem-solving algorithms. Assignment upload was also used administratively as proof of attendance. (2) *Group Solution to Assignment*: The second portion of the synchronous lecture was its most critical because it reviewed all portions of the assignment immediately after student upload. In the case of homework, each multiple choice option was discussed using presentation slides to explain underlying physical reasoning. Review of mini-exams similarly described the physics of the problem, followed by explanation

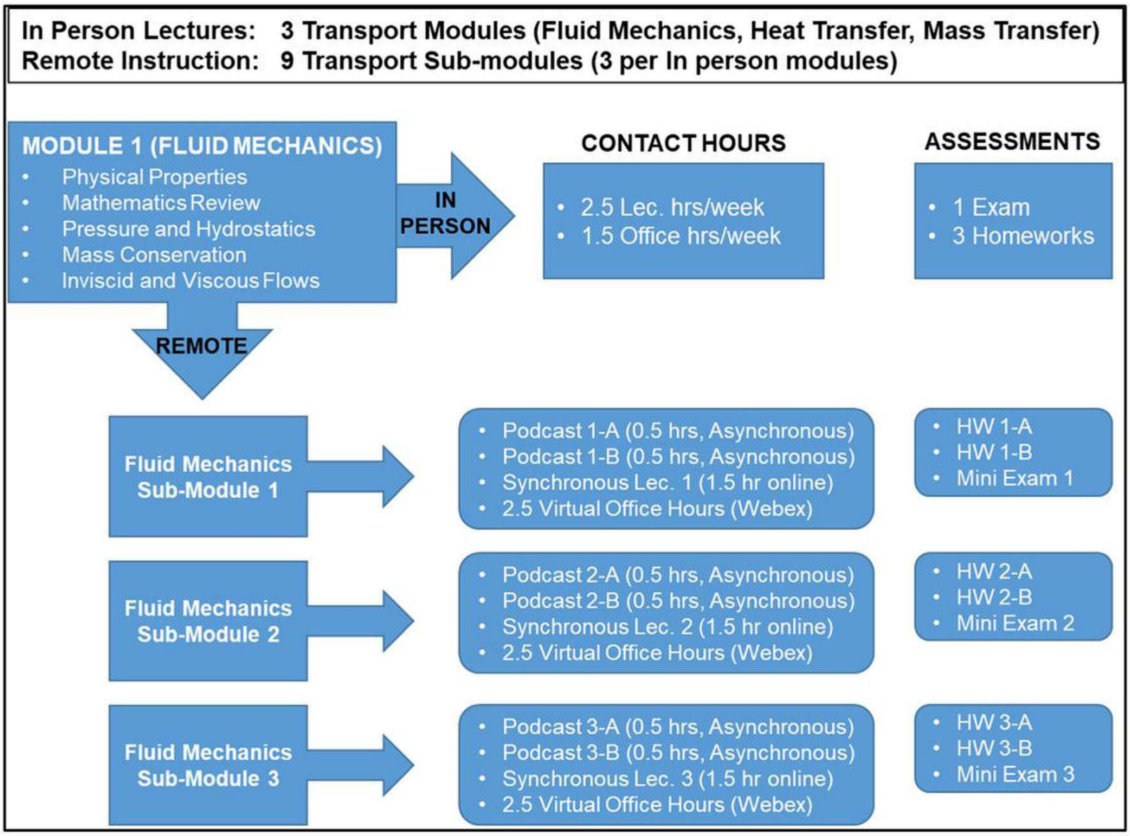

FIGURE 1. Summary of the teaching and assessment styles used for in person lectures vs. hybrid remote instruction via asynchronous podcasts and synchronous online sessions. Differences in the numbers of examinations, mini-examinations, homework assignments, hours in lecture, and instructor availability through office hours are shown. Note that while only Module 1 (fluid mechanics) is shown as a detailed example, all modules follow the same hybrid format.

and justification of the engineering algorithm used for solution. Time for student questions was allotted in between each question and at the end of completed solutions, each using a recitation style setting. Students could use audio or text to pose questions to the class and instructor. (3) *Concept Review*: The final portion of the synchronous lecture reviewed the current analytical concepts and connected them with forthcoming podcast material using a focused, synchronous group problem. As before, the end of each lecture confirmed upcoming administrative dates and assignments.

Virtual Office Hours

A significant part of this hybrid model was instructor availability through office hours. While in person instruction provided an open session once per week, remote instruction scheduled virtual open hours (via webex or zoom) the day after each podcast and synchronous online lecture. As per Fig. 1, this schedule retained the same number of course contact hours.

REFLECTION

Overall Performance

Student performance assessed using remote mini-exams in the 7-week online portion of the course was higher than that measured using in person exams during the same period of the previous 2019 term. As shown in Fig. 2a, a linear increase in the average of each mini-exam was measured, while appropriate grouping of remote mini exams compared against in person exams illustrated a 15% increase in student performance overall as per Fig. 2b. This result can be attributed to the active and problem-based learning principles applied during remote instruction, where students reflect on the physical meaning of new concepts, develop a problem-solving algorithm for the application at hand, and are engaged in understanding (and questioning!) multiple ways to interpret or decode the problem.[4] A larger number of small assignments also helped students understand the level of technical

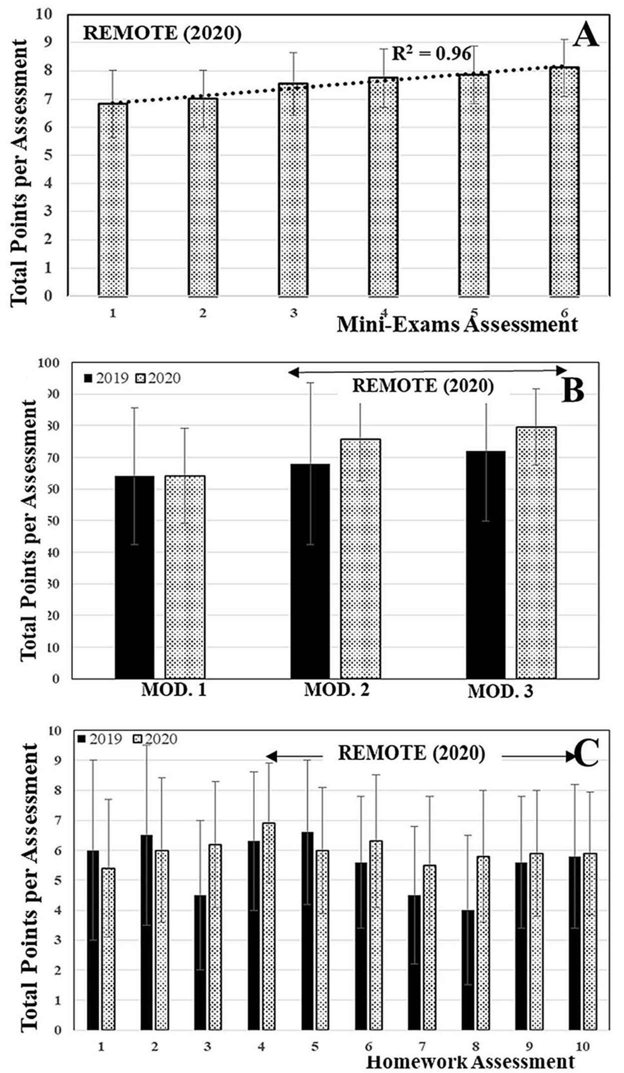

FIGURE 2. Differences in course outcomes measured between remote instruction of the 2020 semester and 2019 in person instruction. (a) Average scores of 6 mini-examinations used during remote instruction. (b) Comparison of average scores for the 3 transport modules presented (Mod. 1, Mod. 2, and Mod. 3) using grouped remote mini-exams of 2020 remote instruction (hashed) and full length exams during in person instruction (black) of 2019. (c) Average scores for homework assignments during remote (hashed) and in person instruction (black).

rigor required per question, while newfound opportunities to revisit recorded explanations and examples helped bolster student mastery of the material. Moreover, we argue that the time restrictions imposed by smaller assignments reduced the potential for plagiarism.[3] This result helped instructors use the assessments to guide course progression more appropriately.

By contrast, homework scores remained surprisingly comparable (with no statistical difference, $p > 0.05$) for remote and in person instruction, as per Fig. 2c. This result is puzzling because the assignments were less challenging than mini-exams, although it is noted that overall homework performance was mediocre with a mean of ~ 50% for both instructional models. Continued lackluster performance may be attributed to the competing time constraints of STEM courses, which become especially challenging for growing numbers of undergraduates who often work part time to meet educational expenses or lack support structures for higher education.[5]

Problem-based learning and active learning have been previously shown to increase student performance in STEM courses.[4] Unfortunately, its principles have been sparsely applied in online settings due in part to a lack of uniform technological support (e.g., LMS, software) and low implementation among faculty colleagues.[6] However, the emergency transition to remote instruction reduced these barriers to thereby enable lessons learned across departments and institutions. The results presented here demonstrate increased student performance in engineering courses when active and problem-based learning are used, and suggests that a hybrid teaching and assessment model can benefit the remote instruction of many technical undergraduate courses rather than transport alone. Such positive data can help influence BME faculty in future development of online materials, as many universities prepare for complete or partial remote instruction.

STUDENT ENGAGEMENT AND SATISFACTION

One surprising consequence of more frequent and remote assessments was increased student-faculty engagement. As shown in Fig. 3a, participation in virtual office hours skyrocketed overall with nearly a quarter of the class in regular attendance for the entire period, compared to less than 15% class attendance for 15–20 min time periods in the previous year. This outcome is likely because virtual office hours reduced physical barriers and scheduling constraints in meeting with the instructor, while remote interactions (with or without video) simultaneously helped students overcome fears or hesitations in asking questions.

In addition, we note that synchronous Q&A discussion immediately following each assignment greatly boosted student engagement with problem-solving. As seen in Fig. 3b, group lectures included an average of 32 min of questions during remote instruction compared with 21 min of student questions during in person instruction, or a 34% increase of student queries overall from diverse groups of students. This may be attributed to both the ability and willingness of students to discuss their own problem-solving algorithms

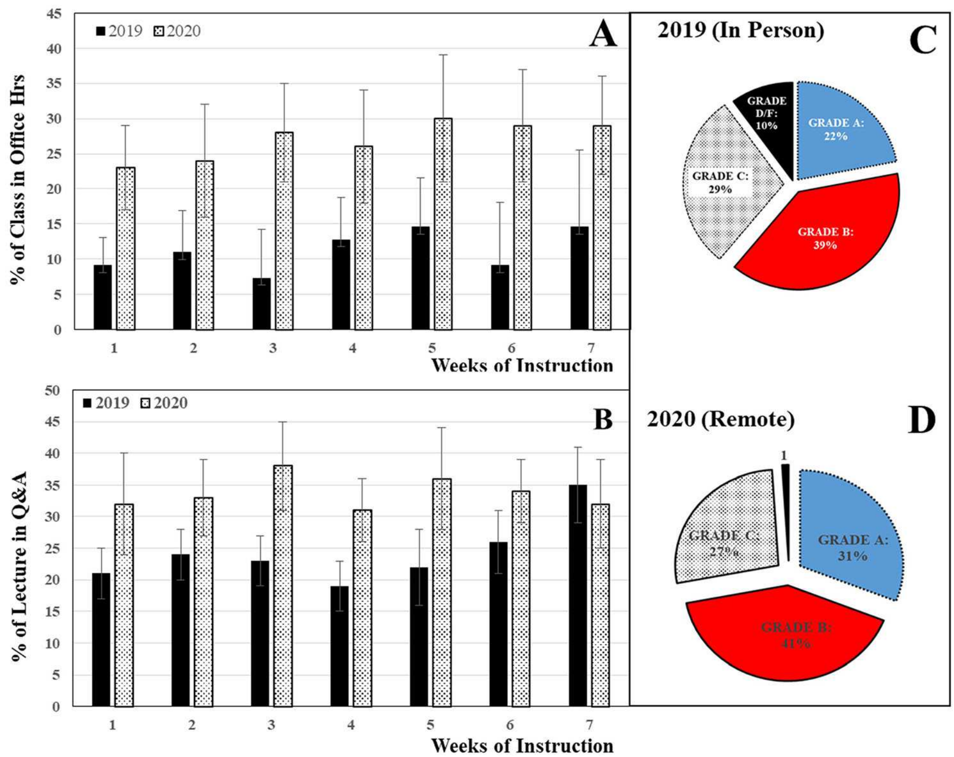

FIGURE 3. Metrics of overall student participation and engagement during remote and in person instruction. (a) Maximum percentage of enrolled students who attended virtual office hours during weeks of 2020 remote instruction (hashed) vs. attendance during the same weeks of in person instruction (black) in 2019. (b) Percentage of synchronous lecture time used for student-initiated questions during weeks of remote, synchronous lectures (hashed) and during the same weeks of in person instruction (black) the previous year. Overall student grade distribution during (C) 2019 in person instruction and (d) 2020 remote instruction.

while the application was fresh in their minds, compared to exam discussion in the proceeding lecture typical of in person instruction. We note that student participation was known to comprise only 10% of the course grade for both in person and remote instruction. Overall course grades were also seen to increase during online instruction as the portion of students receiving a grade of ''A'' increased from 22% during in person instruction to 31% during remote instruction while maintaining the same technical standards. In addition, the portion of students receiving a non-passing grade of ''D'' or ''F'' decreased from 10% during in person instruction to 1% during remote instruction, as per Figs. 3c and 3d. This may also be attributed to the increased student engagement observed with the hybrid methodology used. Lastly, we note that student reception of this hybrid model was positive, with 64% enjoying the combined teaching and assessment style, 11% requesting more synchronous lecture time, 13% requesting a larger percentage of podcast lectures, and 12% remaining neutral.

Challenges

While hybrid remote instruction and assessment produced several positive effects, some challenges remain to be addressed in future online implementation of engineering courses.

1. *Remote Tools*: Several students experienced difficulty in uploading remote assignments because of disparities in education support, such as slower internet connections and multiple learners using a shared space or computer. This data is particularly troubling because such disparities disproportionately affect non-traditional students, e.g., first in college, disabled students, under-represented minorities, and second career adults.[2,5] Fair and uniform implementation of remote instruction with increasing numbers of non-traditional undergraduates requires programmatic and technological infrastructure to provide access to private laptops and standardized software to all enrolled students.

2. *Grading*: While the use of mini-exams to promote active learning improved overall student performance, the grading required is extremely time consuming.[1,4] This factor is especially difficult in the immediate aftermath of the pandemic, where university budget cuts are expected to dramatically reduce support for teaching assistants and graders. Individual faculty and BME departments must, therefore, develop cooperative approaches to support hybrid assessments that benefit undergraduate engineering education.

Future

Undergraduate instruction of transport phenomena will continue to include asynchronous podcasts of solved problems to supplement in person or remote synchronous lectures. This accessible media helps students review concepts and problem-solving algorithms, as needed, to formulate very specific questions that aid student comprehension. Further, our Biomedical Engineering Department as a whole has begun to form faculty teams for instruction of core courses, such that a group of 2–3 instructors collectively develop asynchronous materials to be used each term. This core group will leverage the data collected here to additionally offer virtual office hours that help alleviate barriers to student participation and supplement availability of the primary course instructor.

In summary, experiences learned from recent transitions to remote instruction provide significant opportunities for development of new materials and assessment strategies that help elevate student online comprehension and engagement. Success in prolonged online instruction, however, depends upon technological infrastructure to provide uniform resources, and creative faculty solutions to support active and problem-based learning across departments.

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REFERENCES

[1]Linsenmeier RA, Saterbak A. Fifty years of biomedical engineering undergraduate education. Ann Biomed Eng. 2020;48(6):1590–1615.

[2]Lepek D, Vigeant MA, Silverstein DL, Keith JM. How we teach: transport phenomena and related courses. In: ASEE annual conference & exposition (Paper ID #13167). 2015.

[3]VanDeGrift T, Dillon H, Camp L. Changing the engineering student culture with respect to academic integrity and ethics. Sci Eng Ethics. 2017;23(4):115–1182.

[4]Freeman S, Eddy SL, McDonough M, Smith MK, Okoroafor N, Jordt H, Wenderoth MP. Active learning increases student performance in science, engineering, and mathematics. Proc Natl Acad Sci USA. 2014;111(23):8410-8415.

[5]Bushey-McNeil J, Ohland MW, Long RA. A focus on non-traditional students and non-traditional course delivery methods. In: ASEE annual conference & exposition (Paper ID #9164). 2014.

[6]Muenks K, Canning EA, LaCosse J, Green DJ, Zirkel S, Garcia JA, Murphy MC. Does my professor think my ability can change? Students' perceptions of their STEM professors' mindset beliefs predict their psychological vulnerability, engagement, and performance in class. J Exp Psychol Gen. 2020. https://doi.org/10.1037/xge0000763.

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