Student Attendance at Pharmacology Lectures and Its Relation to Exam Performance in the Era of Lecture Capture: A Two-Year Analysis.

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ABSTRACT

Background: Students can now often choose to attend live lectures or review recordings of the lectures made using lecture-capture technology. However, data on lecture attendance in such cases is scarce, and there are few comparisons of the learning outcomes of the different learning approaches. This study reports data relevant to this issue.

Methods: Attendance data was collected at 13 of 40 voluntary lecture sessions in the Medical Pharmacology course in Fall 2013 (192 students) and Fall 2014 (207 students) by use of an audience-response system. All 40 lectures were recorded using lecture-capture, and students could attend lectures or review the online recordings and PowerPoint files as desired. The data illuminated the features of student lecture attendance and its relation to exam performance.

Results: Only 25-31% of students attended any given monitored lecture, and only 12-14% exhibited high attendance (>80%); 41-52% of students did not attend any monitored sessions. On average, exam scores of students with high lecture attendance were significantly higher than those of other students with a significant shift in scores to higher ranks. Exam scores of students with intermediate to low attendance (77-8%) did not differ from those of non-attending students. The exam scoring advantage associated with high attendance remained evident 20 weeks after the Fall semester when students took a comprehensive NBME exam in pharmacology.

Conclusions: Only a small fraction of students had high attendance at live voluntary lectures providing foundational material. On average, students with high attendance had higher exam scores even though all students had unlimited access to the identical material on-line. The exam scoring advantage associated with high attendance appeared to be long-lasting. The data indicate that high attendance at live lectures was part of a very successful learning approach for some students.

Keywords:

Student attendance

Exam performance

Learning approaches

Audience-response system

Lecture attendance

Lecture capture

BACKGROUND

Faculty lectures have been a classic teaching format in medical education for generations. However, student attendance is now often voluntary due to lecture capture technology that records lectures and uploads the video files to online learning management systems where students can study the material whenever desired (1-3). This is beneficial for students whose learning approach, lifestyle or distance from school is ill-suited for live attendance. Such technology has also fostered the development of approaches like the "flipped classroom" where students are instructed to study lecture recordings online before attending live sessions using active-learning methods to enhance learning (4,5). Indeed, some have proposed that live lectures should be replaced with blended methods that couple self-study of online material with live active-learning methods to develop advanced reasoning skills (6,7).

The lack of mandatory attendance requirement at lectures that are recorded, and approaches like the flipped classroom give the impression that review of online materials enables learning as effectively as live attendance. However, data on this issue is sparse and variable in its findings. Some studies found lower exam performance in students using online recordings to replace lecture attendance (8-10); while others reported similar efficacy (11-13). A 2010 meta-analysis comparing traditional and on-line approaches (14) concluded that blended approaches with online offerings were as effective as traditional instruction. However, that report also noted that blended approaches typically benefited from greater learning time, more instructional materials, differing pedagogies and greater collaborative opportunities than lectures (14). This imbalance in learning time, educational resources and instructional approaches remains evident in virtually all studies comparing traditional lectures to flipped classrooms or other on-line or blended learning methods (15-19). Given such advantages, it is surprising that improved

academic performance is not a consistent finding in studies comparing flipped classrooms to traditional lectures (16,18,20-23). This suggests that the learning efficacy of live lecture attendance may be underestimated.

Our understanding of the learning efficacy of live lectures is greatly clouded by a lack of detailed information on student attendance. In particular, what proportion of the class attends any lectures, what is the average attendance level among those present, how variable is attendance over time, and how do these factors relate to exam performance? Most modern data on lecture attendance is largely based on student surveys with limitations in participation, accuracy, and detailed attendance data. Moreover, studies have shown that attendance decreases over the course of a semester and from year to year (24-28). This complicates efforts to assess the value of live lectures relative to online offerings since students may initially attend and later switch to on-line viewing. Such attendance decreases might reflect recognition that online viewing enables learning as well as live attendance (2). However, surveys assessing student attitudes indicate that diverse factors influence attendance decisions. Thus, time of day, subject matter, other commitments, lecturer quality, lifestyle choices, distance from school, time-savings from accelerated replays and other convenience factors all prominently figure in attendance decisions (2,12,25-27-31). Overall, the learning efficacy of live lecture attendance versus review of on-line recordings remains unresolved but is an important issue since material covered in lectures typically provides foundational knowledge that other teaching formats build upon.

We report two years of observational data that enabled a characterization of student attendance at voluntary lecture sessions and an analysis of its relation to exam performance. We accomplished this with attendance data collected from a subset of the voluntary lectures in which an audience-response system (ARS) was used to pose questions that students answered using

wireless response devices (32,33). In addition to answer choices, transmitted responses identified students in attendance. This provided information on the attendance habits of students and enabled analyses of the relation of attendance to exam performance.

METHODS

Data collection: We collected data on exam performance and student attendance at voluntary lecture sessions during the Medical Pharmacology 1 course for 2nd year medical students during the Fall semesters in 2013 and 2014. The course begins in early August and ends in late December and included 40 voluntary lecture sessions covering foundational material. Mandatory laboratory demonstrations, problem-solving exercises and clinical case conferences built upon the material covered in voluntary sessions. Thirteen of the voluntary lectures between mid-October to early December included an interactive component where an ARS (Turning Point 5, Turning Technologies, Youngstown, OH) interfaced with PowerPoint to pose multiple-choice questions that students answered using wireless response devices (Turning Technologies ResponseCard RF). Lectures involved PowerPoint presentations in an auditorium with equipment and software that created synchronized audio and screen-capture recordings (Camtasia Recorder, TechSmith, Okemos, MI). Lecture recordings (including ARS questions) were promptly posted to an online learning management system for student use. All students also had access to the PowerPoint files for each lecture before and after the session.

Students were provided with advance notice of which voluntary lectures would include interactive questions to encourage attendance and alert them to bring their wireless response devices. Wireless response devices were mandatory equipment for medical students since the ARS was used to administer required formative quizzes in 2nd year courses. Each response

device was registered to a specific student and transmits its identifying code along with the student responses. Turning Technologies software (Turning Pont 5) automatically generated an ARS session file that was converted to Excel spreadsheets for use in the data analysis. The ARS assigned attendance points to students who answered at least 50% of the questions presented in a session. Attendance points were only used to track and calculate student attendance during the voluntary lecture sessions that were monitored; they had no bearing on the formal assessment of student performance in the course. Attendance data from monitored sessions, and data from exam result spreadsheets were compiled and analyzed to examine the relation of student attendance to exam performance.

Statistical analysis: Compiled data were analyzed using NCSS Data Analysis software (version 11; Kaysville, UT). Datasets of exam performance and student attendance were initially subjected to linear regression analysis. Datasets were subsequently stratified into groups based on different levels of attendance. Due to differences in the 2013 and 2014 course schedules, minor variations in attendance groups were used in different years (see Results). Attendance stratifications that yielded groups with equivalent exam averages were often re-stratified into a smaller number of groups to enhance statistical power. The datasets were analyzed using ANOVA followed by multiple comparison tests (Tukey HSD test, etc.) or by t-tests when only two means were analyzed. Effect size analyses on exam averages were done using Cohen's *d* with datasets that had been stratified into two groups (34,35); this statistic measures effect size as a proportion of the standard deviation.

Frequency distribution analyses were performed using Pearson's Chi-squared statistic. Effect size analyses on such data used the phi (w) statistic (34); which measures categorical correlations. The pattern of attendance in different attendance groups was assessed by calculating

the absolute value of the difference in attendance during different course sections ("attendance variation").

The criterion of significance for ANOVA, Chi-squared and multiple comparison tests were $P<0.05$. Meaningful small, medium, and large effect sizes were defined as Cohen's *d* >0.2, 0.5 and 0.8 for comparison of two means, and *w*>0.1, 0.3 and 0.5 for Chi-square analyses.

RESULTS

Student Attendance Levels: Student attendance during the voluntary lecture sessions was measured in 13 of 40 sessions during the Fall semester by using an ARS to pose interactive questions. Fig. 1 (left panel) shows the levels of student attendance recorded in the monitored sessions in 2013 and 2014. High levels of attendance (>80%) were exhibited by only 12-14% of the enrolled students; 34-47% exhibited intermediate to low attendance (77-8%), and 41-52% did not attend any of the monitored voluntary sessions. On average, 25-31% of the students were present at voluntary lectures that were monitored, and the average attendance rate among students who attended any of the monitored lectures was 51-52%. Among attendees, 20-30% exhibited high attendance (>80%); 20-40% exhibited 77-46% attendance; and 40-50% exhibited 38-8% attendance (Fig. 1, right panel).

Relation of Student Lecture Attendance to Performance in Course Exams.

Complete datasets of the attendance level and the average of all 4 exams for each student were initially subjected linear regression analysis. The results revealed weak positive correlations that provided little insight; 2013 $r=0.173$, $r^2=0.030$, $P=0.016$; 2014 $r= 0.072$, $r^2=0.005$, $P=0.302$. For a more discriminating analysis the datasets were segregated into groups based on attendance levels. Figure 2 (left panel) shows the average scores for students

exhibiting high, intermediate to low, or no attendance during the monitored class sessions during each of the 4 exams held during the Fall 2013 semester. The group with high attendance (>80%) had higher exam scores (+3 to 6 percentage points) compared to groups with intermediate to low or no attendance. This difference was significant for exams 1, 3 and 4, The 2013 data also indicated that students with intermediate to low attendance did not exhibit a significant scoring advantage relative to students with no attendance.

Fig 2 (right panel) shows the corresponding data for Fall 2014. Unlike Fall 2013, exam 1 scores were not related to attendance rates in Fall 2014; this may reflect higher attendance and higher exam scores that are typically seen in the first section of the course. However, on exams 2, 3 and 4 the group with high attendance had higher exam scores (+3 to 5 percentage points) compared to groups with intermediate to low or no attendance. This difference was significant for exams 3 and 4. Thus, the 2014 data for Exams 2, 3 and 4 generally matched the Fall 2013 data showing that high attendance was associated with a significant scoring advantage relative to students with intermediate to no attendance. The Fall 2014 data also confirmed the Fall 2013 data showing that students with intermediate to low attendance did not exhibit a scoring advantage relative to students with no attendance.

The relatively small numbers of students exhibiting high attendance weakened the statistical power of analyses focusing on a single exam. Thus, we analyzed the aggregate exam averages of the different attendance groups. Figure 3 (upper left panel) compares the aggregate exam averages of groups of students exhibiting high, intermediate to low, or no attendance in Fall 2013. The high attendance group had a significantly higher aggregate exam average than the groups with either intermediate to low or no attendance (+5.9 to 5.5 percentage points). The dataset was then subjected to effect size analysis to determine if the performance difference was

meaningful. For this analysis, students with intermediate to low or no attendance were pooled since there was no significant difference in their aggregate exam averages. Effect size analysis comparing the aggregate 2013 exam average in the high attendance group to the average of the rest of the students indicated that this was a meaningful difference (Cohen's $d = 0.605$). This dataset was then subjected to frequency distribution analysis to assess the relation of student attendance to relative scoring rank (Fig. 3 lower left panel). The frequency distribution analysis revealed that high attendance was associated with a significant shift in aggregate exam averages towards the high rank coupled with a decrease in the intermediate and low ranks. Effect size analysis indicated that this was a meaningful difference (effect size $w = 0.185$). Thus, students with high attendance were 71% more likely to have a high rank, and 50% less likely to have a low rank, compared to students with intermediate to low or no attendance.

Figure 3 (upper right panel) shows the aggregate averages of Exams 2-4 for the high attendance group and the groups exhibiting intermediate to low or no attendance in Fall 2014. High attendance was again associated with significantly higher aggregate exam averages (+5.4 percentage points) relative to intermediate to no attendance. Effect size analysis indicated that this was a meaningful difference (Cohen's $d = 0.537$). Frequency distribution analysis revealed that high attendance was again associated with a shift in the number of students with averages in the higher rank coupled with a decrease in the number of students scoring in the lower rank (Fig. 3, lower right panel). Effect size analysis indicated that this was a meaningful difference ($w = 0.151$). Thus, students with high attendance were 60% more likely to have an upper rank, and 37% less likely to have a lower rank compared to students with intermediate to low or no attendance.

We also analyzed the aggregate exam averages using an attendance stratification that gave a larger number of attendance groups (i.e., 100-80%, 77-46%, 38-8%, 0%). In both 2013 and 2014 the high attendance group (100-80%) was unique in displaying a consistent increase in exam performance in both 2013 and 2014 (data not shown).

Relation of Student Lecture Attendance to Performance on a Pharmacology Exam Prepared by the National Board of Medical Examiners (NBME).

The Medical Pharmacology 1 course in the Fall semester is followed by a Medical Pharmacology 2 course in the Spring semester that concludes with a comprehensive NBME shelf exam in pharmacology covering material taught in both semesters. The NBME exams were given 20 weeks after the end of the Fall semester when the attendance data was collected. In both years the group with high attendance had a higher NBME exam average than groups with intermediate to low or no attendance (+4.5 points in Spring 2014 and + 3.1 points in Spring 2015); this difference was significant for the Fall 2013 class (t-test $P < 0.02$), and approached significance in the Fall 2014 class (t-test $P < 0.13$). To increase the statistical power of the NBME exam data analysis, we transformed the NBME scores to give a mean of 55.6 for both classes, with no change in the variance of either class. The data were then pooled and analyzed. The pooled data showed that the high attendance group had a significantly higher NBME average (+3.8 pts.) than the intermediate to low and no attendance groups (Fig. 4, left panel). For effect size analysis, students with intermediate to low or no attendance were pooled since there was no significant difference in their NBME exam averages. Effect size analysis indicated that there was a meaningful difference in the NBME exam averages (Cohen's $d = 0.403$). Frequency distribution analysis of NBME scores showed that high attendance was associated with a

significant shift in scores towards the higher rank coupled with a decrease in scores in the lower rank (Fig. 4, right panel); effect size analysis indicated that this was a meaningful difference (effect size *w*= 0.138). Students with high attendance were 50% more likely to have an upper rank and were 48% less likely to have a lower rank. Thus, on average, high lecture attendance in the Fall semester was associated with increased NBME exam scores almost 5 months later.

DISCUSSION

After the introduction of lecture capture technology, it became apparent that attendance at voluntary lecture sessions progressively declined during the semester, particularly after exam 1. This declining attendance has been widely reported (24-28), and in the present study 41-52% of the class never came to any of the monitored lectures in October through early December, and only 25-31% of the class were present at any of the monitored sessions. It was anticipated that most students attending lectures would have high attendance. However, this was not true; only 20-30% of those attending (12-14% of the class) had high attendance (>80%); the attendance average of the rest was much lower (34% in 2013 and 41% in 2014). This indicates that most students attending any given lecture had a highly variable pattern of attendance.

High attendance variability has prompted others to use linear regression analysis to correlate attendance level to course outcomes such as exam performance (13,28,36-39). Such analyses have generally found low correlations with coefficients of determination (r^2) below 0.1. Although the correlations were positive, such data suggested that attendance was not a major determinant in exam performance for most students. Similar correlations were found in the present data with r values below 0.2 in both 2013 and 2014, However, linear regression

analyses assume there is a linear relationship between two variables, and analysis of the present datasets showed that this was not true.

When students were stratified into groups based on attendance levels it was evident that, on average, students with high attendance (>80%) consistently achieved higher exam scores than students with intermediate to low or no attendance. This was true in 7 out of the 8 in-house exams administered in Fall 2013 and 2014 and confirmed in the aggregate exam averages of Fall 2013 and Fall 2014. The scoring advantage associated with high attendance also appeared long-lasting. On average, students with high attendance displayed higher scores in a comprehensive NBME pharmacology exam given 20 weeks after the end of the Fall semester. Frequency distribution analyses demonstrated that students in the high attendance groups had a consistent shift towards higher exam scores coupled with a decrease in lower scores. This was true for both the in-house exams and for the NBME exam.

The reasons why some students adopted a high attendance approach was not addressed but presumably reflects their preferred learning style and desire for live interactions with classmates and faculty. In this regard, it is notable that surveys of student attitudes regarding attendance indicate that many students prefer live attendance to study of recorded lectures, but factors related to lifestyle, other commitments and convenience can over-ride such preferences (11,26,28,29). Interestingly, students who did not attend any monitored sessions had the most consistent attendance pattern and the most specialized study approach: attendance had been abandoned in favor of online or other resources. Nonetheless, on average, this approach did not yield an exam scoring advantage. The reasons why so many students chose not to attend lectures was not addressed but surveys of student attitudes indicate that a multitude of factors play a role

in such decisions, many of which relate to convenience rather than perceived learning outcome (2,11,24-27,28-31).

At this point it should be noted that there were many students in the top ranks of the class who had intermediate to no attendance. Thus, other learning approaches worked well for some students. Conversely, high attendance did not guarantee high exam scores since some students with high attendance had scores that placed them in the middle or lower ranks of the class. Nonetheless, a learning strategy that increases the chance of earning a score in the middle ranks may be highly valued by some students given the varying academic strengths of individual students.

Although our data show that the high attendance group had increased exam performance relative to those with lower attendance, the behavioral characteristics of students with high lecture attendance might also contribute. Thus, personal attributes such as organization, discipline and motivation that may foster high attendance may make some students better prepared than others for learning. However, such attributes should not be viewed as innate character traits; they are more likely to reflect the influence of years of learning experiences that rewarded class attendance and shaped behavior accordingly.

Modern pedagogy emphasizes the value of ‘active learning’ that actively engages students in the material being taught. Thus, it is ironic that students are routinely instructed to prepare for active learning sessions by passively reviewing on-line lectures recordings that may offer no advantages beyond convenience for many students and may be less advantageous for students preferring live classes. Given the present findings, it may be prudent to reconsider suggestions for the replacement of live lectures with on-line lecture recordings. Nevertheless, this is not meant to imply that on-line offerings or blended approaches lack value, or that

traditional lectures cannot be improved by use of active-learning methods (40). Rather, the use diverse teaching formats may be advantageous since there appears to be considerable variation among students in the efficacy of any single approach.

CONCLUSIONS

Only a small fraction of the class had high attendance (>80%) at the lecture sessions monitored. High lecture attendance appeared to be part of a highly effective learning approach based on higher exam scores in the group of students using this approach. Although some students had similarly successful exam outcomes with intermediate to low or no lecture attendance, on average, exam scoring was lower in groups where on-line study had largely replaced lecture attendance. Further analysis of the relation of live lecture attendance to learning is warranted.

DECLARATIONS

Ethics Approval and Consent to Participate: The protocol used was reviewed by the Committee for Protection of Human Subjects of New York Medical College (approval L-12,058, January 27, 2017). The protocol was given a waiver of informed consent /HIPPA waiver based on the minimal risk exemption for research in educational settings involving normal educational practices [45 CFR 46.104(d)(1) Exemption 1]

Consent for publication: Not applicable.

Availability of data and materials: The course datasets used in the study are not publicly available as they are based on exam scores and attendance data of identifiable students. Datasets are available from the corresponding author on reasonable request after modification to remove identifiers.

Competing Interests: The authors declare they have no competing interests.

Funding/Support: The authors declare there was no external body involved in the design of the study, the collection, analysis and interpretation of the data, or in writing the manuscript.

Author's Contributions: C.A.P. was responsible for all phases of the research (conception, design, data collection, data analysis and interpretation, manuscript preparation). M.A.C. contributed to the design, data collection, and editing of the manuscript. All authors have read and approved the manuscript.

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List of Abbreviations:

ARS – audience response system

NBME – National Board of Medical Examiners

Author's Information:

C.A.P. has been the course director of the Medical Pharmacology courses at NYMC for over 20 years. He is also the course director of two advanced graduate courses and is a teaching faculty member in many other courses. He has actively encouraged, supported, and implemented diverse innovations in medical education in the courses he directs or teaches in. This includes the use of lecture-capture technology - which provides on-line lecture recordings that are a valuable learning resource for students. The medical education research of C.A.P. seeks to better understand the diverse learning approaches used by students and explore how such diversity can be more effectively assisted by versatile methods of curriculum delivery. Lecture attendance is one of many approaches students use to achieve their educational goals and should neither be ignored nor over-emphasized.

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FIGURE LEGENDS

Figure 1: Characterization of student attendance at voluntary lecture sessions where interactive questions were posed using an ARS during Fall 2013 and 2014. Left panel: Distribution of students in groups stratified based on attendance level. Right panel: Percent of attending students in groups stratified based on attendance level.

Figure 2: Relation of attendance to performance on pharmacology exams in Fall 2013 and 2014. Exam averages for each attendance group for each of the 4 in-house exams are shown. Data show mean + SEM. Horizontal line through each exam set shows class average for exam. P values are for t-tests comparing 100-83% attendance group to pooled group with 77-0% attendance.

Figure 3: Relation of Student Attendance to Aggregate Exam Averages and Scoring Distribution in Fall 2013 and 2014. Upper left panel: aggregate average of exams 1-4 in 2013 in the indicated attendance groups. Data show mean + SEM. Upper right panel: aggregate average for exams 2-4 in 2014. Dashed lines show the aggregate exam average for the entire class. Lower panels: scoring distribution for the indicated attendance groups. For both 2013 and 2014, intermediate to no attendance groups were pooled as indicated to increase the statistical power of the analyses. For 2014, only two scoring ranks were used to increase statistical power.

Figure 4: Relation of Fall voluntary lecture attendance to scoring on the NBME pharmacology exam given 20 weeks after the end of the Fall semester. Left panel: NBME exam scores from Spring 2014 and Spring 2015 were transformed to yield a mean of 55.6 for each year (no change in variance) and then pooled and average scores determined for the indicated attendance groups. The dashed line indicates the pooled NBME average for the two classes. Right panel: The NBME exam scoring distribution for the indicated attendance groups. Note: the NBME used scaled scores in 2013 and 2014 (national average ~ 50); scores are not % correct scores.