

22 The studies addressing this question have arrived at different conclusions regarding the effectiveness of
23 each presentation style, making it unclear which method is more effective. For example, Susskind
24 determined that using PowerPoint in an Introduction Psychology course did not impact performance but
25 did increase student attitudes (1). This study, which utilized two different classes, delivered half of the
26 lectures by traditional chalk-talk while the other half were delivered using PowerPoint, with the lectures
27 counterbalanced in each class to control for differences in the topics presented. Alternatively, Savoy et.
28 al. reported that students maintained 15% more of the verbal information given by the instructor using
29 the chalk-talk approach for a given lecture, even though the students indicated a preference for
30 PowerPoint (2). A similar study in a medical physiology course that examined one lecture presented in
31 both styles supported Susskind's conclusion as no significant difference in outcomes between chalk-talk
32 versus PowerPoint was observed, although the students reported significant differences in learning
33 metrics between the two approaches. For example, in post-class surveys the students indicated that
34 PowerPoint was better for "clarity of words" and "summarizations" while chalk-talk was superior for
35 "clarity of concepts", "learning to draw diagrams", and "understanding the subject" (3). Similar results
36 were obtained by Kumar comparing PowerPoint to chalk-talk for 5th year surgery students using post-
37 class surveys (4). PowerPoint ranked higher for content and clarity while chalk-talk ranked higher for
38 stimulating interest and advancing understanding, although the difference for this last category was
39 minimal (4). Bartsch et. al. found that in a social psychology course PowerPoint slides with both images
40 and text decreased performance compared to overheads (5). This same report concluded that inclusion
41 of non-related images on a PowerPoint slide was detrimental in retaining the concept presented. The
42 bottom line is that multiple studies exist that show a student preference for PowerPoint over chalk talk
43 (6,7) or vice versa (8,9), and there is not clarity to which method is a more effective teaching tool.

45 Why is there such a discrepancy in studies that compare PowerPoint to chalk-talk? I postulate although
46 the studies cited above were well-controlled, it is difficult to compare the two methodologies in this
47 manner because these lectures/courses were not designed around a given presentation format. More
48 importantly, there is a learning curve for the instructor to effectively deliver a lecture using PowerPoint
49 or chalk-talk and comparing these methods with only one or a subset of lectures does not allow for
50 instructor mastery of the different approaches. Therefore, instructor skill in each approach could lead to
51 different outcomes. Thus, the results of studies comparing these approaches are mixed (10).

52

53 I am aware of only one study addressing the effectiveness of PowerPoint versus chalk-talk in my own
54 field of microbiology, and it concluded that although students preferred PowerPoint, use of a
55 blackboard was the most effective; however, the methodology for assessing effectiveness is not clear
56 (11). Here, I harness my own experiences teaching the large lecture course “Microbial Genetics” at
57 Michigan State University for the last ten years, the first seven of which utilized PowerPoint and the last
58 three that utilized chalk-talk, to analyze the effectiveness of PowerPoint versus chalk-talk in
59 microbiology education at the undergraduate level. An analysis of course metrics including course
60 reviews, course attendance, and student assessment indicates that the chalk-talk approach was superior
61 to PowerPoint in every category.

62

63 **Methods**

64 **Course structure**

65 The data are gathered from five semesters of “MMG 431:Microbial Genetics” given in the fall semester
66 at Michigan State from 2013 to 2017 in which I was the sole instructor. PowerPoint was exclusively used

67 as the lecture format in 2013 and 2014 while a chalk-talk approach was primarily used in 2014-2017.
68 Course enrollment for these years in parentheses is 2013 (123), 2014 (151), 2015 (155), 2016 (134), and
69 2017 (150), and it was taught in a lecture hall that seats about 200 students. The course met three times
70 a week for 50-minute lectures. Students were evaluated by three midterm exams consisting of 53
71 multiple choice questions and a cumulative final exam consisting of 95 multiple choice questions
72 covering key concepts from throughout the semester.

73

74 **Lecture format**

75 During 2013 and 2014, PowerPoint slides were projected onto two screens at the front of the class, and
76 one lecture had on average 20-25 slides. An electronic file of the PowerPoint slides was provided to the
77 class before the lecture. The class was asked ~2-4 “think:pair:share” questions every lecture, which has
78 been demonstrated to increase cognitive learning in large lecture classroom (12-14). For the chalk-talk
79 approach, a touch screen laptop was utilized and projected to the same two screens, and lectures were
80 hand-drawn with an electronic stylus using the program OneNote. Using OneNote rather than a
81 traditional blackboard better projected the chalk-talk lectures, allowed the use of multiple colors, and
82 enabled rapid switching to other programs such as PowerPoint, iClicker software, or a web browser. The
83 lecture started as a blank white page, and text and pictures were drawn with a touch screen stylus using
84 various line widths and colors. Each lecture was a new OneNote page that was a subset of an individual
85 folder so all lecture notes were saved and could be referenced later. The lecture notes were not
86 distributed to the class. PowerPoint was used sparingly (~0-2 slides per class) to show complex
87 diagrams, structures, or more commonly (~2-4 slides per class) to project the same “think:pair:share”
88 questions that were used for the PowerPoint lectures. As the intention during these five years was to
89 provide the best learning experience and not execute a tightly controlled study, there were

90 modifications in course structure and procedures from year to year. For example, on-line homework was
91 assigned in 2014-2016, but not in 2013 and 2017. In 2017, the audio of all lectures was recorded and
92 posted on the central course page allowing students to re-listen to lectures (but no lectures notes were
93 provided).

94

95 **Student course evaluation**

96 At the end of the semester, students are asked to complete an anonymous 21-question Student
97 Instructional Rating System (SIRS) evaluation form that is standard for all classes at Michigan State
98 University (Table 1). Students can opt out of completing these evaluations, and it is not known how
99 many students completed them for each year. These questions are scored from 1 to 5 using the Likert
100 scale of: (1) Superior (2) Above Average (3) Average (4) Below Average and (5) Inferior. The questions
101 are then aggregated into the six general categories listed in Table 1, and a mean score for each category
102 is determined. Students can also submit specific comments about the course although this is optional.
103 During the five years analyzed here, the percentage of class that submitted a specific comment was
104 2013 (31.7%), 2014 (25.8%), 2015 (37.4%), 2016 (23.9%), and 2017 (21.3%). These comments were
105 binned into three categories of positive (mostly positive comments), neutral (an equal mix of positive
106 and negative comments), or negative (mostly negative comments) by four individuals that are not
107 connected to this study or the course without the evaluators knowing the year the comment was made.

108

109 **Course participation**

110 During all five years, students were given 2-4 active learning “think:pair:share” exercises during the
111 lecture. These exercises consisted of a question proposed to the class, followed by the class dividing into

112 groups for ~ 1 minute to discuss. Each student then used an iClicker to submit a response, and the
113 question and correct answered were discussed as a class. Students were assigned participation points
114 based on how many responses they submit, and credit was not dependent on selecting the correct
115 answer. iClicker responses were used to measure student attendance as presented in Figure 4.

116

117 **Ethical considerations**

118 This study was reviewed by the Michigan State University Institutional Review Board and found to be
119 exempt under 45 CFR 46.101(b) 4. All data used is anonymous and cannot be linked to individual
120 students.

121

122 **Results**

123 **Rationale for implementing chalk-talk lectures**

124 I have been the course administrator and sole instructor for the junior/senior level undergraduate
125 course “MMG 431:Microbial Genetics” at Michigan State University since 2013, and I co-taught this
126 course with one other instructor from 2009-2012. Therefore, for this study I only analyze data from
127 2013-2017 where I was the only instructor and course administrator. This course is taught once a year
128 with student enrollments ranging from 121 to 155, and it is required for graduation with a degree in
129 Microbiology. From 2009-2014, I had utilized a standard lecture course format with PowerPoint slides
130 interspaced with active learning “think:pair:share” exercises. The students were given access to
131 printable PDFs of all lecture slides before class, and these were intended to be an outline for further
132 note taking during class. Because the lecture slides were available, many students preferred to bring
133 their laptop computers and followed the lecture electronically. From my perspective, many of the

134 students were not attentive during the lecture. Visitors to the course also noted that students often
135 participated in non-class related activities on their electronic devices such as social media. Students
136 expressed both to me in person and on in-class evaluations that too much material was covered too
137 rapidly. For example, this comment from 2014 is representative of many student comments during the
138 years when PowerPoint was used: “I feel that the appropriateness of the amount of material the
139 instructor attempted to cover and the pace at which the instructor attempted to cover the material was
140 too great.”

141

142 To attempt to address both of these problems, in 2015 I stopped primarily lecturing with PowerPoint
143 and rather presented the lecture in a chalk-talk style. Using this approach, I wrote the information as I
144 lectured, and the students were required to take notes in real time. The students were not provided any
145 written notes either before or after class, and thus they were required to actively take notes and pay
146 attention during the lecture. I did continue to implement 2-4 think:pair:share exercises during class, and
147 the students received participation points for each response regardless of whether they were correct.
148 On occasion, complicated structures were shown as PowerPoint slides, although this was rarely greater
149 than 1 slide per lecture and many lectures presented no information using PowerPoint. As this course
150 was taught by the same instructor teaching the same general material, with two years of PowerPoint
151 (2013-14) and three years of chalk-talk (2015-17), an analysis of course data provides an excellent
152 opportunity to gauge which approach was more effective in a microbiology large lecture course.

153

154 **The instructor perspective**

155 I found the students were clearly more engaged when lecturing using chalk-talk and few actually used
156 laptops or other electronic devices during class. The students asked more questions during the lecture

157 and more actively participated when discussing think:pair:share activities. Another advantage was that
158 lecturing using the chalk-talk style allowed more flexibility than PowerPoint. For example, if a student
159 asked a question about a topic that was not in the original lecture, I was able to switch directions mid-
160 class without being constrained by the next slide. I would often think of new think:pair:share questions
161 during the lecture and could stop and present these to the class, which was not feasible using only
162 PowerPoint. Essentially, my perspective was that lecturing using chalk-talk is a much more active and
163 engaging experience for both myself and the students than using PowerPoint, and I was better able to
164 connect with the class.

165

166 **Student course reviews indicate students prefer chalk-talk over PowerPoint**

167 To assess student perception of the two lecture formats, student responses to the 21 questions grouped
168 into six categories, as listed in Table 1, from SIRS evaluation forms from 2013-2017 were assessed. The
169 scores for these six categories from 2013 to 2014 where PowerPoint lecturing was used were quite
170 consistent with scores ranging from 1.95 to 2.88 graded on the Likert scale with (1) Superior (2) Above
171 Average (3) Average (4) Below Average and (5) Inferior (Fig. 1A). Starting in 2015, when chalk-talk was
172 implemented, the scores of every category improved annually. In 2017, the scores ranged from 1.37-
173 1.8. In fact, the lowest numeric value for each category was measured in 2017 (Fig. 1A). In 2013 and
174 2014, only the “Student/Instructor” category was less than 2, but all six categories were below 2 in
175 2017. One possibility to explain these results is that I simply improved generally as an instructor over
176 time; however, this hypothesis is unlikely for several reasons. First, 2013 was my fifth year teaching this
177 course so I was already highly experienced with the PowerPoint approach and the course material.
178 Second, the scores from 2013 to 2014 are stable, and they are consistent with SIRS scores from 2009-
179 2012. In fact, half of the categories had worse scores in 2014 than in 2013. Improvement was only

180 observed in 2015 when the format was changed to the chalk-talk style, and this improved every year as I
181 became more adept at lecturing using this method.

182

183 To determine which category exhibited the greatest improvement, I subtracted the lowest scores (all in
184 2017) from the highest scores (either in 2013 or 2014) in each category (Fig. 1B). “Enjoyment of the
185 Course” and “Course Demands” showed the greatest gain in student evaluation scores increasing by
186 over 1 point followed by “Instructor Involvement” at 0.95, but all categories exhibited increases greater
187 than 0.48.

188

189 The final data that was analyzed from the SIRS evaluations, which is perhaps the most informative, is
190 taken from the specific comments section. Four individuals not connected to this study independently
191 analyzed the specific comments provided by the students for all five years and binned them into positive
192 (i.e. no negative comments), negative (i.e. no positive comments), or neutral categories (i.e. a mix of
193 positive and negative comments). Specific comments were not required to complete the form and
194 ranged from 29-56 entries per year. The mean percentage and standard deviation for each category of
195 the four evaluators per year is shown in Fig. 2. In 2014, negative comments were significantly greater
196 than either positive or neutral comments, but this switched when chalk-talk was implemented as
197 positive comments were significantly greater than neutral or negative comments from 2015-2017.
198 Neutral comments also declined during this time. Positive comments from 2015-17 expressed
199 enthusiasm for the chalk-talk style with a representative comment being:

200 “His way of lecturing is so great. I wish it would be mandatory for every single class at MSU to
201 mimic his teaching style. He writes down his notes and discusses them with us. it shows us if he
202 can write it down we can too. It’s not too fast but we learn a lot.”

203

204 **Chalk-talk improves grades**

205 To assess the difference in course outcomes between the two lecture formats, I analyzed course grades
206 across each year. The percentage of the class that received the highest score of 4.0 versus a failing grade
207 of 0 is plotted for each year (Fig. 3). As seen with the SIRS scores, these percentages were quite similar
208 between 2013 and 2014 when PowerPoint was used, and these are reflective of the course from 2009-
209 2012. However, students receiving the highest grade of a 4.0 showed a consistent increase from 2015 to
210 2017 reaching a total of 40% of the class in 2017. The large increase in 4.0 scores from 2016 to 2017 may
211 be attributed to the posting of audio recordings of the lecture, nevertheless, 2015 and 2016 both have a
212 higher percent of students receiving 4.0 than 2013 or 2014. Conversely, students receiving the lowest
213 grade of 0 decreased in 2015 to 2017. Students who failed the course dropped from 17.2% in 2013 to
214 2.7% in 2017. A similar decrease was observed for lower scores of 1.0 and 1.5, but mid-level grades of
215 3.5, 3.0, 2.5, and 2.0 remained constant during this time frame (data not shown).

216

217 Analyzing score adjustments for final grades also highlights the effectiveness of the chalk-talk approach.
218 The data shown in Fig. 3 are the scores that would have be assigned based on the percentage of points
219 received, but in 2013 and 2014 small but equal increases were given to all students to adjust for course
220 difficulty. No such bumps were given in 2015-2017 as the raw scores were improved such that this grade
221 adjustment was no longer necessary.

222

223

224

225 **Course attendance**

226 Because students are no longer provided lecture notes, I hypothesized that course attendance would
227 increase. Course attendance can be assessed by analyzing the average percentage of iClicker points
228 obtained for the class for responses to in-class questions. These results show increased participation
229 when chalk-talk was used as the three highest participation scores for these five years are from 2015-
230 2017 (Fig. 4).

231

232 **Learning of key concepts**

233 Switching to chalk-talk certainly reduced the amount of material that I could cover, as discussed below,
234 which could account for the changes observed. However, it is important to note that my syllabus,
235 including the key concepts and dates they would be covered, was unchanged from 2013-2017. To assess
236 retention of key concepts at the completion of the course, I analyzed the results of the final exams from
237 2013-2017. These exams are cumulative, and they test the students on key concepts from the entire
238 course. Because the final exam focuses on key concepts, and less on individual details, these exams
239 were highly similar from 2013-2017 and can serve as a standard to compare concept retention. The
240 highest median final exam scores occurred in 2015-2017 when chalk-talk was used while the lowest
241 median final exam scores were 2013-2014 when PowerPoint was used (Fig. 5A). This increase in final
242 exam scores occurred even though many students had less motivation to study for the final in 2015-
243 2017 because they had obtained higher grades on the first three midterm tests throughout the
244 semester.

245

246

247 **Discussion**

248 My analysis of course metrics from the years 2013-2017 indicates that in my large microbiology lecture
249 course, lecturing with the chalk-talk method was far superior to a traditional PowerPoint lecture. The
250 students preferred the chalk-talk approach, better retained key concepts, and they ultimately achieved
251 higher scores. These five years are not a tightly controlled study as small differences were implemented
252 each year to try and improve the course. For example, I suspect the increase in students receiving a 4.0
253 in 2017 was in part due to the audio of the lectures being made available to the class. But the general
254 trend is clear in all data examined, and there is clearly a demarcation between the years when
255 PowerPoint lecture was used versus the chalk-talk format.

256

257 I estimate that the course material was reduced around 40% when chalk-talk was used so the students
258 in 2013 to 2014 were responsible for more material. This reduction was a conscious decision on my part
259 as it had become clear that too much material was being covered. This reduction further highlights one
260 of the main advantages of the chalk-talk approach. Using this approach forced me to focus on only the
261 most important concepts and remove extraneous information. The reduction of material was not a
262 removal of any of the core concepts, but rather a reduction in specific examples of a given topic. For
263 example, rather than providing the students with four examples of sRNA regulation, I now only give
264 them two. But understanding what sRNAs are and how they function remains a core concept of the
265 course. This is evidenced by the fact that my lecture syllabus remained unchanged from 2013-2017. In
266 essence, switching formats forced me to reduce the content of the course to the key microbial genetics
267 concepts that I felt the students should learn, which is process that is being undertaken in all science
268 fields as we continually expand our information base (15, 16). Moreover, the cumulative final exam
269 scores increased when chalk-talk was used, providing evidence that key concepts were better retained.

270

271 Furthermore, an analysis of the SIRS scores does not suggest that the improvements to the course are
272 entirely due to reduced course material. Importantly, the amount of information taught was identical in
273 2015-2017. If the improvements observed were simply due to a reduction in the amount of material,
274 one would predict that SIRS results in 2015 would be similar in 2016 and 2017. However, this is not the
275 case as improvements were observed in 2016 and 2017 compared to 2015, even though the amount of
276 material did not change. Such a trend is also evident when examining specific SIRS comments (Fig. 3)
277 and the final grades (Fig. 4) I speculate that these further improvements were due to my own increased
278 experience with the chalk-talk format. This five-year study also highlights the important point that it is
279 problematic to truly measure effectiveness of PowerPoint compared to chalk-talk by simply presenting
280 one or a subset of lectures in each format and comparing the results. In order to gain the most benefit
281 of the chalk-talk style, the course must be designed around this format and the instructor must be
282 experienced using it as the largest benefits of using chalk-talk only became apparent only in 2017 (year
283 3). A strength of the data presented here, although it is not completely controlled, is that it spans
284 multiple years allowing for a more real-world conclusion that accounts for instructor experience and
285 course variation. Even though small changes were made to my course from year to year, the overall
286 benefits that were observed upon switching to chalk-talk are quite clear. Whether a similar reduction of
287 material when using PowerPoint would lead to similar gains is a question that requires further study.

288

289 There are several other factors to consider when comparing PowerPoint to chalk-talk. One important
290 consideration of switching to chalk-talk is that research has shown seeing the lips and face during
291 speech can promote increased comprehension, and if the instructor's back is turned as during writing on
292 a blackboard this cannot occur (17). However, by writing on a lap-top that was projecting on screens

293 while facing the students overcomes this limitation. A large body of evidence indicates that actively
294 taking notes, and later revisiting those notes for exam preparation contributes to increased learning (18-
295 21). The chalk-talk approach I used certainly increased the amount of note-taking compared to using
296 PowerPoint where the slides were provided before the lecture. On the other hand, excessive note-
297 taking could lead to excessive demands on student's cognitive function preventing learning during the
298 lecture (19) and providing the slides beforehand could allow the students to spend less time note-taking
299 leading to increased learning during class (22, 23). Although Babb and Ross found that providing lecture
300 notes before class compared to after class increased participation and class attendance, there was no
301 significant impact on exam scores (24). Whether or not chalk-talk approaches with partial or complete
302 lecture notes outlines would improve performance over providing no lecture notes would be an
303 interesting question to study further.

304

305 In the digital information age, it is challenging to maintain student engagement in large lecture courses
306 with electronic devices offering a constant distraction. Banning these devices or disabling internet
307 access in classrooms has been attempted as one solution to this problem. The data shown here clearly
308 indicate that another solution is to use a chalk-talk approach, with limited PowerPoint slides for difficult
309 diagrams, that requires active listening and note-taking without written lectures posted. My findings are
310 consistent with other studies that conclude mixed lecture formats are the most effective lecturing styles
311 (25-27). The data presented here show that when used appropriately, chalk-talk lecturing styles can be
312 substantially more enjoyable and effective as the primary lecturing format in a large microbiology
313 lecture course.

314

315

316

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323

324 **References**

- 325 1. Susskind JE. 2005. PowerPoint's power in the classroom: enhancing students' self-efficacy and
326 attitudes. *Computers and Education* 45:203-215.
- 327 2. Savoy A, Proctor RW, Salvendy G. 2009. Information retention from PowerPoint and traditional
328 lectures. *Computers and Education* 52:858-867.
- 329 3. Prabhu R, Pai KM, Prabhu G, Shrilatha. 2014. A Lecture in Medical Physiology- PowerPoint versus
330 Chalkboard. *South East Asian Journal of Medical Education* 8:72-76.
- 331 4. Kumar SD. 2016. Perception of medical students on lecture methods:Power Point or
332 Chalkboard? *IJHRMLP Vol: 03 No: 01: 77-80*.
- 333 5. Bartsch RA, Cobern, KM. 2003. Effectiveness of PowerPoint presentations in lectures. 41:77-86.
- 334 6. Jabeen N, Ghani A. 2015. Comparison of the traditional chalk and board lecture system versus
335 power point presentation as a teaching technique for teaching gross anatomy to the first
336 professional medical students. *JEMDS* 4(11):1811-17.
- 337 7. Harley KN, Jankar J, Mohod KM. 2015. Perception of first MBBS medical students towards
338 different teaching aids used in teaching learning process: A comparison between power point
339 versus chalkboard teaching. *Int J Adv Res Biol Sc* 2(7):71-80.
- 340 8. deSa SB, Keny MS. 2014. Power point versus chalkboard based lectures in pharmacology:
341 Evaluation of their impact on medical student's knowledge and their preferences. *Int J Adv*
342 *Health Sci.* 1(5):10-1.
- 343 9. Parvin R, Md Haque N, Ahmed N, Ahmed R, MI, Ara R, Rahman MM, Bhattacharjee S,
344 Bhattacharjee S, Rafiqueuddin AKM. 2010. Is audio visual method better than tradi-tional for
345 medical students? A survey report. *Bangladesh J Med* 21:60-4.
- 346 10. Inoue-Smith Y. 2016. College-based case studies in using PowerPoint effectively. *Cognet*
347 *Education* 3:1-15.

- 348 11. Arora D, Mahajan MK, Kaur M. 2016. Quality of Medical Education System-Increasing or
349 Decreasing. *Journal of Evolution of Medical and Dental Sciences* 5:7547-7549.
- 350 12. Morse D, Jutras F. 2008. Implementing conceptbased learning in a large undergraduate
351 classroom. *CBE-Life Sci. Educ.* 7:243–253.
- 352 13. Regassa LB, Morrison-Shetlar AI. 2007. Designing and implementing a hands-on, inquiry-based
353 molecular biology course. *J. Coll. Sci. Teaching* 36:36–41.
- 354 14. Freeman S, Eddy SL, McDonough M, Smith MK, Okoroafor N, Jordt H, Wenderoth MP. 2014.
355 Active learning increases student performance in science, engineering, and mathematics.
356 *Proceedings of the National Academy of Sciences* 111(23). 8410-8415
- 357 15. Gregory E, Lending C, Orenstein AN, Ellis JP. 2011. Redesigning Introductory Biology: A Proposal.
358 *Journal of Microbiology and Biology Education.* 12(1):13-17.
- 359 16. Labov JB, Reid AH, Yamamoto KR. 2010. Integrated Biology and Undergraduate Science
360 Education: A New Biology Education for the Twenty-First Century? *CBE Life Sciences Education.*
361 9(1): 10–16.
- 362 17. Campbell R. 1999. Seeing speech in unexpected places. *The Psychologist.* 12(9):446-449.
- 363 18. DiVesta, FJ, Gray SG. 1972. Listening and note taking. *Journal of Educational Psychology,* 63, 8–
364 14.
- 365 19. Kiewra KA, DuBois NF, Christensen M, Kim S, Lindberg N. 1989. A more equitable account of the
366 note-taking functions in learning from lecture and from text. *Instructional Science,* 18, 217–232.
- 367 20. Kiewra KA, DuBois NF, Christian D, McShane A, Meyerhoffer M, Roskelley D. 1991. Note-taking
368 functions and techniques. *Journal of Educational Psychology* 83:240–245.
- 369 21. Knight LJ, McKelvie SJ. 1986. Effects of attendance, note-taking, and review on memory for a
370 lecture: Encoding vs. external storage functions of notes. *Canadian Journal of Behavioural*
371 *Science* 18:52–61.
- 372 22. Austin JL, Lee MG, Thibeault MD, Carr JE, Bailey JS. 2002. Effects of guided notes on university
373 students’ responding and recall of information. *Journal of Behavioral Education* 11:243–254.
- 374 23. Pardini EA, Domizi DP, Forbes DA, Pettis GV. 2005. Parallel note-taking: A strategy for effective
375 use of Webnotes. *Journal of College Reading and Learning* 35:38–55.
- 376 24. Babb KA, Ross C. 2009. The timing of online lecture slide availability and its effect on
377 attendance, participation, and exam performance. *Computers & Education* 52:868–881
- 378 25. Saha N, Tripura K, Das R. 2015. Students’ Opinion towards audio visual aids used in lecture
379 classes. *IOSR Journal of Dental and Medical Sciences* 14(4):96-100.
- 380 26. Chaudary R, Dullo P, Gupta U. 2009. Attitude of 1st MBBS medical students about two different
381 visual aids in physiology lectures. *Pak J Physiol* 5(2):16-19.
- 382 27. Harley KN, Jankar J, Mohod KM. 2015. Perception of first MBBS medical students towards
383 different teaching aids used in teaching learning process: A comparison between power point
384 versus chalkboard teaching. *Int J Adv Res Biol Sc* 2(7):71-80.

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388

Table 1: Questions on Student Instructional Ratings Systems Evaluation Forms

| Category | Question |
|--------------------------------|---|
| Instructor Involvement | The instructor's enthusiasm when presenting course material. |
| Instructor Involvement | The instructor's interest in teaching. |
| Instructor Involvement | The instructor's use of examples or personal experiences to help get points across in class. |
| Instructor Involvement | The instructor's concern with whether the students learned the material. |
| Student Interest | Your interest in learning the course materials. |
| Student Interest | Your general attentiveness in class. |
| Student Interest | The course as an intellectual challenge. |
| Student Interest | Improvement in your competence in this area due to this course. |
| Student Instructor Interaction | The instructor's encouragement to students to express opinions. |
| Student Instructor Interaction | The instructor's receptiveness to new ideas and others' viewpoints. |
| Student Instructor Interaction | The student's opportunity to ask questions. |
| Student Instructor Interaction | The instructor's stimulation of class discussion. |
| Course Demands | The appropriateness of the amount of material the instructor attempted to cover. |
| Course Demands | The appropriateness of the pace at which the instructor attempted to cover the material. |
| Course Demands | The contribution of homework assignments to your understanding of the course materials relative to the amount of time required. |
| Course Demands | The appropriateness of the difficulty of assigned reading topics. |
| Course Organization | The instructor's ability to relate the course concepts in a systematic manner. |
| Course Organization | The course organization. |
| Course Organization | The ease of taking notes on the instructor's presentation. |
| Course Organization | The adequacy of the outlined direction of the course. |
| Enjoyment | Your general enjoyment of the course. |

Fig. 1A

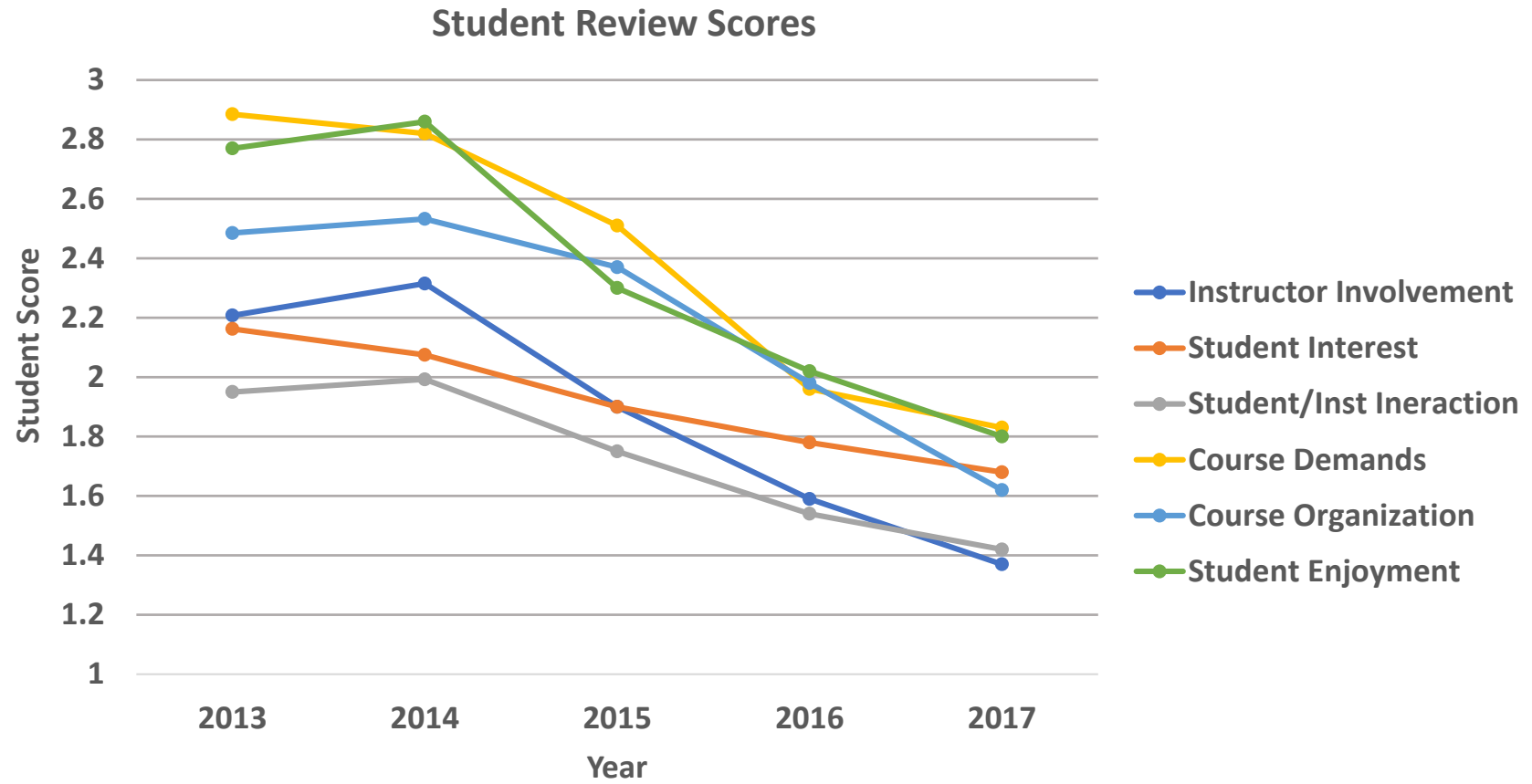


Fig. 1B

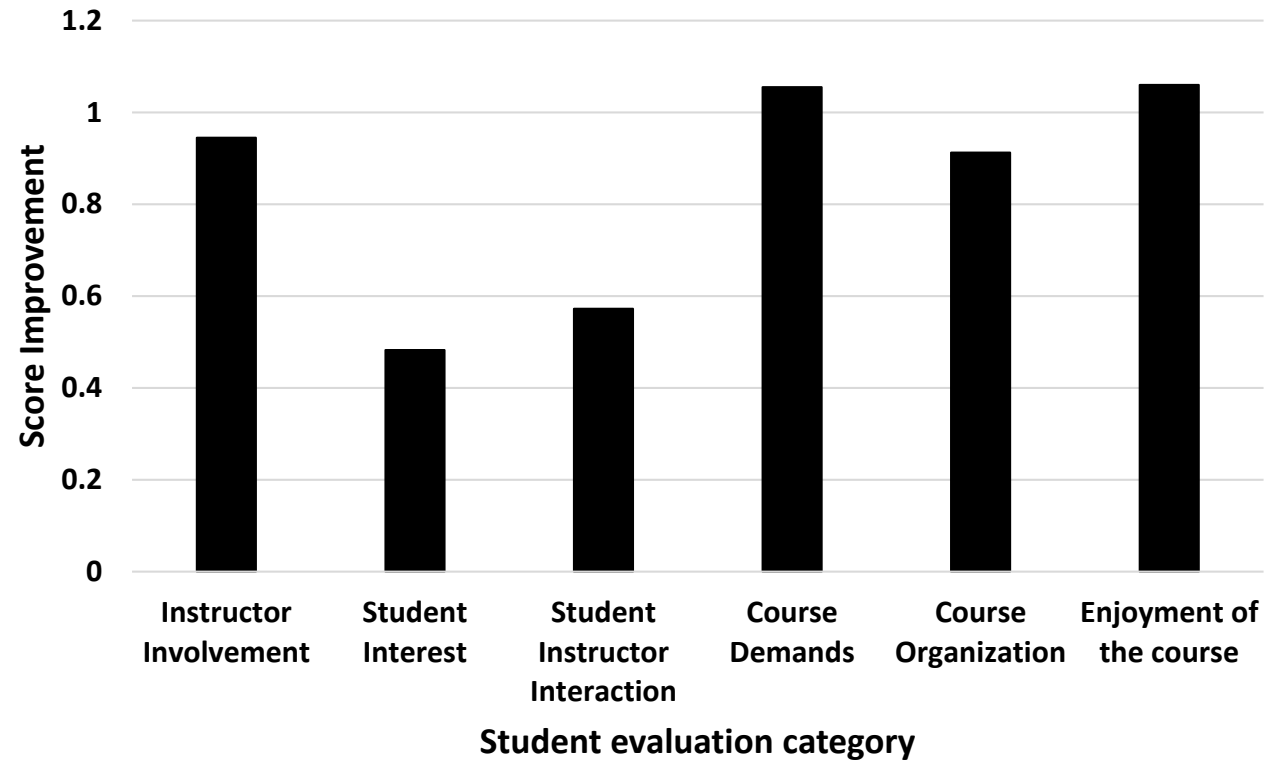


Fig. 1. Analysis of student evaluations. Student evaluation responses from 2013-2017 to the six categories described in Table 1 were analyzed. (A) Student evaluations are grouped into six general categories, and the score from each year is shown with (1) Superior (2) Above Average (3) Average (4) Below Average and (5) Inferior . (B) The maximum increase in scores for each group during this five year period is shown.

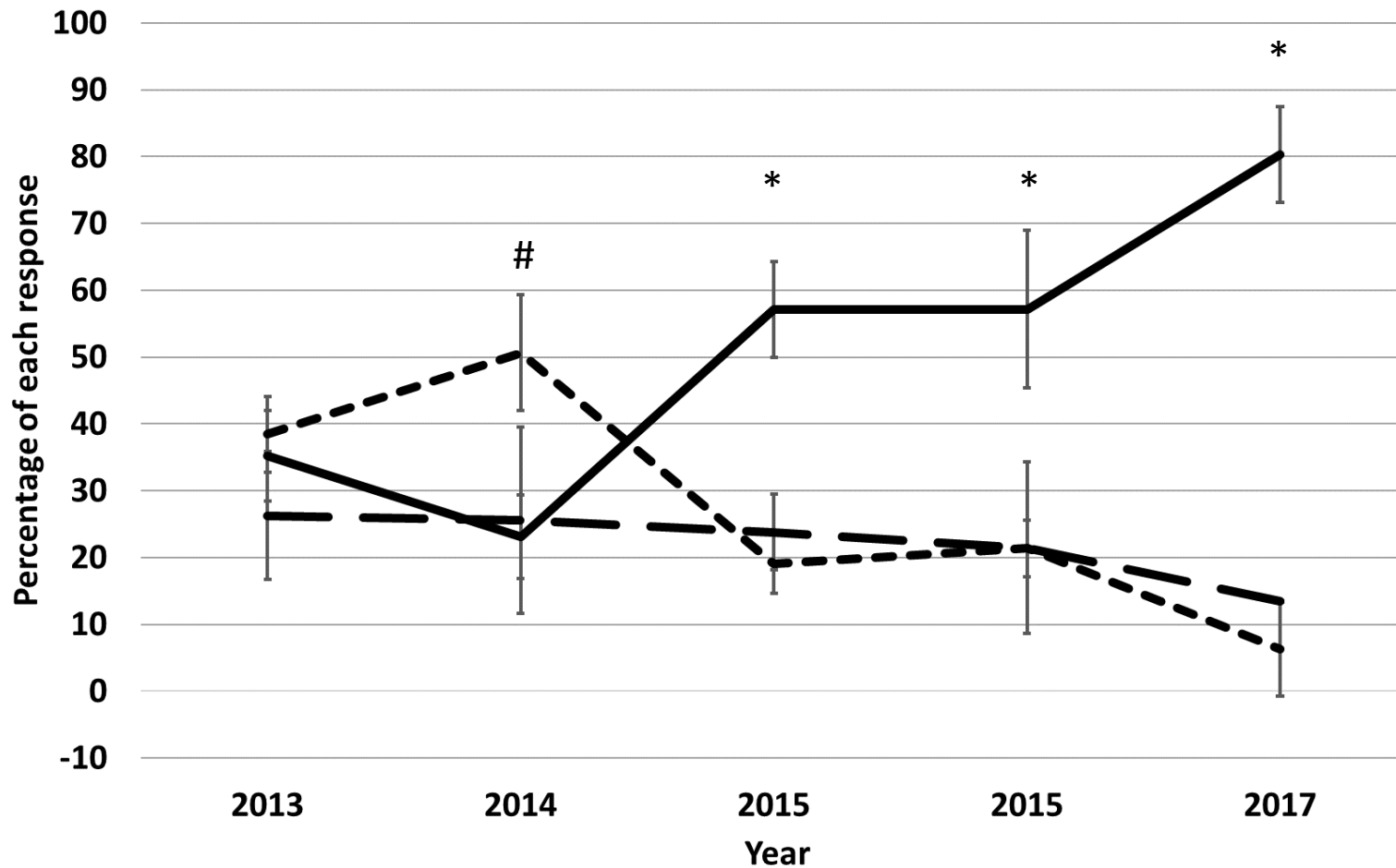


Fig. 2. Student SIRS comments between PowerPoint and chalk-talk. The specific student comments from every student evaluation was grouped as either positive, neutral, or negative by four individuals and calculated as a percentage of the total comments. Solid=positive, large dashes=neutral, small dashes=negative. The mean percentage with the standard deviation is plotted for each year. #-Negative versus positive and neutral ($p < 0.0002$), *-Positive versus negative and neutral ($p < 0.0001$) as determined by a Two-Way ANOVA followed by Tukey's Multiple Comparison Test.

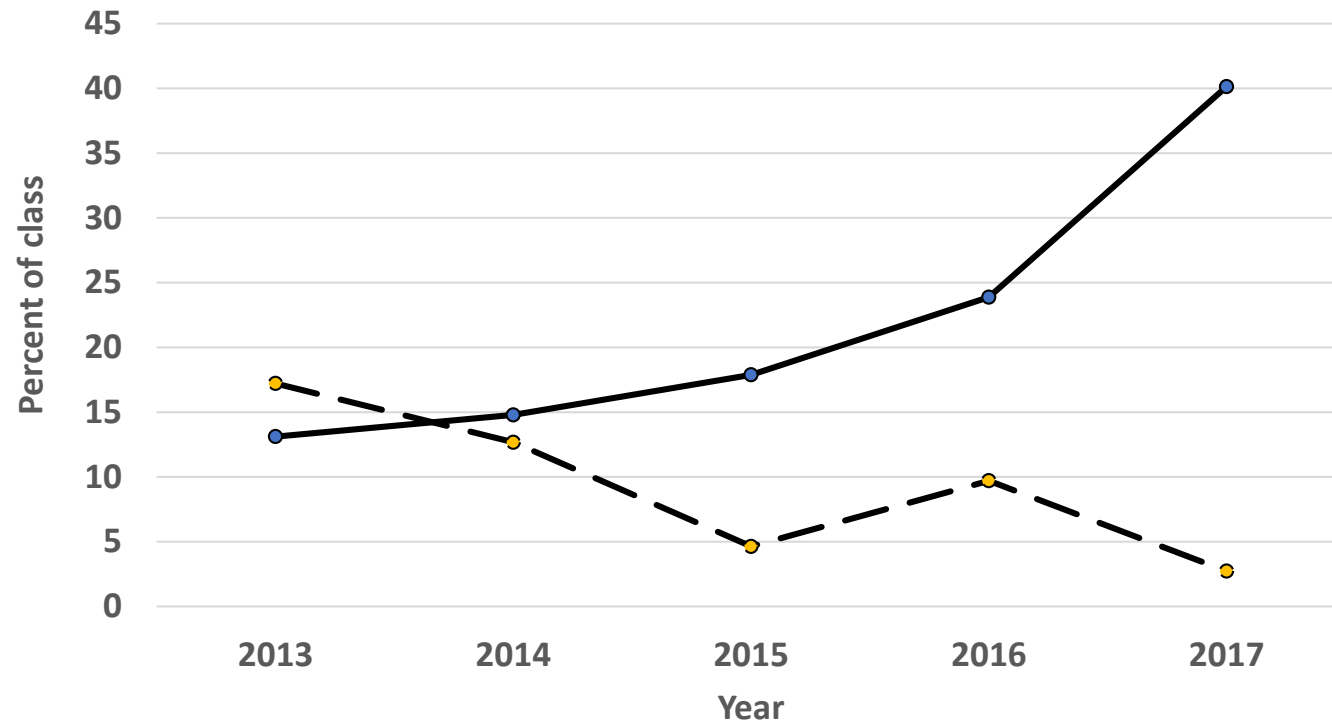


Fig. 3. Student grades increase with chalk-talk methodology. Grades are assigned on a 4.0 scale, and the percent of the class that would receive a 4.0 (solid) versus a failing 0 (dashed) is shown each year.

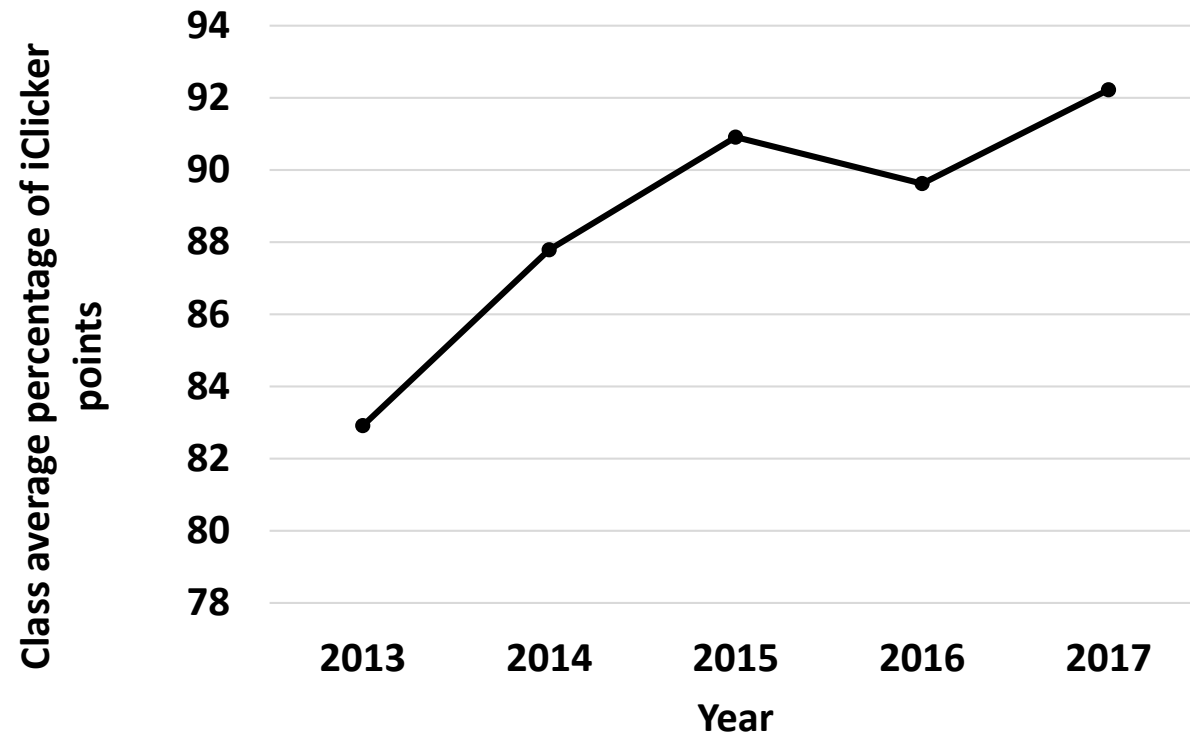


Fig. 4. Student attendance. Student attendance was assessed by calculating the class average of iClicker points obtained during the entire semester. Points were assigned for every in-class question for which a response was registered irrespective of whether the response was correct or not.

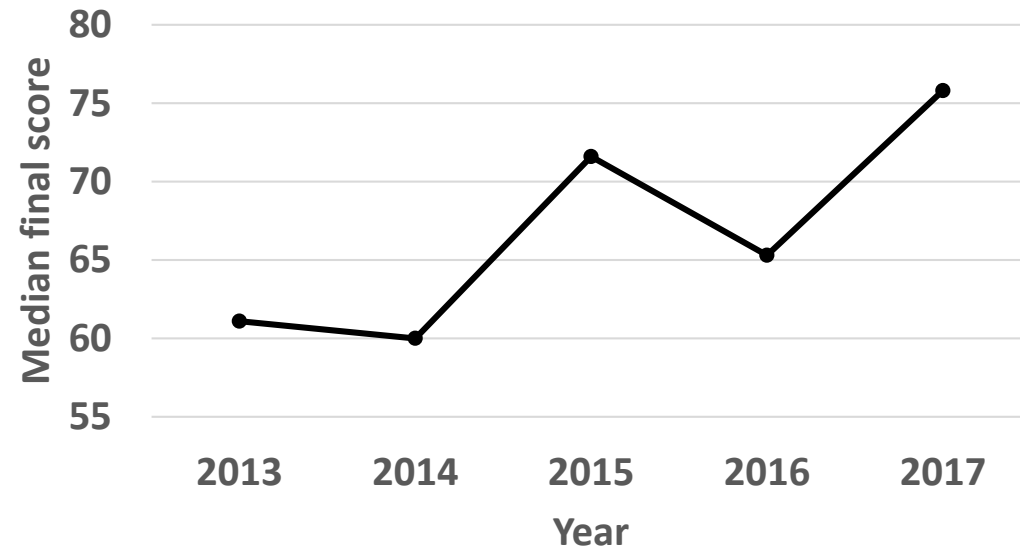


Fig. 5. Comprehensive final analysis. The mean final score each year for the 95 question comprehensive final exam that covers each topic.