

1 **Preparing for class: actions and resources of introductory biology students**

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Abstract

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Instructors want students to be prepared for class. There are several different resources and activities available to help students prepare for class, but very little is known about how students choose to prepare for class in the context of undergraduate biology. In this study, we used content analysis to investigate what students do to prepare for an introductory biology course, and if and how that preparation differed under two different conditions. Students were either directed to search out and choose their resources to prepare for class (choice treatment) or assigned specific pages from a textbook (text treatment). Students in the choice treatment reported preparing for class slightly more often than students in the text treatment, with both groups reporting that they prepared for over three-quarters of classes. However, students assigned specific textbook passages engaged more while preparing than students who had to find their resources. The textbook was a popular resource but second to websites for students who got to choose. Students in both groups performed similarly in the course. This work helps instructors understand what their students may be doing to prepare for class. We provide recommendations to guide instructors on how to help their students prepare for class.

Keywords: undergraduate, class preparation, biology, content analysis,

49 **Introduction**

50 Instructors almost universally want their students to come to class prepared (1–5). Students who are
51 prepared ask more sophisticated questions and perform better on exams (3). Additionally, for instructors to use
52 beneficial active learning pedagogies, students must be familiar with the material so that they can engage with the
53 content and activities during class time. If and how students prepare for class can be influenced by guidance from
54 the instructor.

55 Traditionally, instructors ask students to read chapters from a textbook (6–9). Unfortunately, students
56 typically do not complete broad reading assignments (10, 11). When students do read, they often quickly skim the
57 text instead of engaging deeply with the materials (12–15). However, these studies that describe how college
58 students prepare for class are outside the disciplinary context of biology. Understanding how undergraduate students
59 prepare for class, specifically within the disciplinary context of biology, is important as biology discourse and
60 content are unique.

61 To improve students' interactions with textbooks, biology instructors assign supplementary materials for
62 students to use outside of class such as reading guides (16), quizzes (3, 17), and textbook-affiliated online resources
63 (e.g., Mastering Biology by Pearson Education Inc.; 18). Within classes, instructors also use reading quizzes (19)
64 and clicker-style questions (20) to check for class preparation compliance. Some of these methods are shown to
65 improve reading completion (3) and test scores (16, 17). However, instructors often do not implement these
66 materials because of a lack of awareness, familiarity, or technical support (21). Additionally, instructors may not
67 have the time to create (22) or become familiar with and use these materials (16). Furthermore, textbooks and
68 affiliated resources can be expensive, a cost often shouldered exclusively by students. Therefore, we need to
69 investigate simple and inexpensive instructional interventions for their impact on helping students prepare for class.

70 One option could be to have the students choose how to prepare for class themselves. We are teaching in an
71 era in which copious amounts of information are freely and quickly available online. Students are incredibly
72 resourceful and commonly use the internet to answer many of their everyday questions (23). Moreover, self-
73 determination theory (SDT) (24) describes choice as a motivating experience. Allowing students to make choices
74 give them autonomy in their studies which increases intrinsic motivation (25, 26). Additionally, Enhanced Affective
75 Engagement Hypothesis states that giving students choices increases their attitude, satisfaction, and effort in

76 learning (27). However, giving students choices on what materials they use (i.e., resources) and how they use those
77 materials (i.e., actions) to prepare for class is understudied in the context of undergraduate biology courses.

78 In this study, we investigated the resources and actions students in an undergraduate introductory biology
79 course used to prepare for class. Furthermore, we investigated if that preparation differed between students who
80 were assigned either specific textbook readings or the freedom to choose their resources and actions. Finally, we
81 explored whether course performance was affected by how students prepared for class. We hypothesized that the
82 two treatments would result in students preparing differently, and that the actions and resources students used to
83 prepare for class would affect course performance.

84 **Methods**

85 This work was conducted with approval from the institutional review board at Northern Illinois University
86 (#HS17-0259).

87 **Study Context**

88 This study was conducted at a large four-year, doctoral-granting, regional comprehensive university in the
89 Midwestern United States. The course was introductory cellular biology for biology and related majors. The course
90 met three times a week for 50 minutes and was taught in a large, auditorium-style, lecture hall with enrollment
91 around 100 students per term. The course was student-centered and used active learning (28) with about 40% of
92 class time used for students to work together on projects and discussions, including think-pair-shares and creating
93 models. Course topics included the chemistry of biology, structure and function of large biomolecules and cellular
94 components, metabolic processes, gene expression and regulation, and inheritance.

95 **Study Design**

96 We ran two treatments over two semesters using a quasi-experimental approach (29). For both semesters,
97 one author was the instructor, the same topics were covered, and the format of the courses was the same. In the
98 spring of 2018, students chose what resources they would use to prepare for class (referred to as “choice treatment”).
99 In the spring of 2019, students were assigned specific, narrow readings from a textbook to complete before class
100 (referred to as “text treatment”).

101 For the choice treatment in 2018, we gathered and analyzed data from 91 consenting students out of a total
102 class population of 117 (consent rate of 78%). For the text treatment in 2019, 61 out of 89 students (consent rate of
103 69%) were included in the study. Students from both treatments had similar demographics and backgrounds (Table

104 1). There were no statistical differences between the treatment groups according to χ^2 analyses for categorical factors
105 (i.e., gender, age group, race/ethnicity, class, first generation, transfer status) and t-test for GPA.

106 [TABLE 1 HERE]

107

108 **Assignment**

109 Throughout the semester, students were assigned a list of topics to familiarize themselves with before being
110 covered in each class. This assignment was introduced to students during the first day of class both orally and with
111 an assignment sheet (Supplemental Material S1 - choice treatment, Supplemental Material S2- text treatment). The
112 assignment sheets gave a rationale for the assignment, provided learning goals and objectives, explained how to
113 complete the assignment, described how the assignment would be graded, and listed out a schedule of topics for
114 each class.

115 As evidence of their preparation, students submitted answers to questions in an online form before every
116 class for which they prepared, herein called an “entry.” The questions included: what day they prepared for; if they
117 read the assigned pages (text treatment only); what (else) they did to prepare (i.e., action), what resources they used
118 to prepare (choice treatment only), what they learned during the preparation, and what questions they had regarding
119 the material that arose during the preparation. Submitting an entry for the assignment was one of the ways that
120 students could earn completion points for a participation grade that counted towards 10% of their course grade.
121 Students were given other opportunities (i.e., in-class participation) and slightly more opportunities than necessary
122 to earn the maximum amount of participation points. To earn all the participation points, students had to submit a
123 least 30 entries out of the possible 39.

124 Students in the choice treatment were tasked with choosing their resources to learn about the listed topics.
125 They were given several example resources such as a specific recommended textbook, lecture slides, videos, and
126 practice questions (Supplemental Material S1). Students in the text treatment were assigned narrowed, specific
127 pages from the required textbook that aligned with the topics for each class (Supplemental Material S2). Text
128 treatment students were asked to report additional actions they engaged in besides reading the assigned textbook
129 pages.

130 **Analysis**

131 Students self-reported how they prepared for classes by completing an entry before each class (30). We
132 analyzed the quantity of entries, as well as the number of actions and resources students reported per entry. We
133 compared the quantity of entries students submitted to the quantity we expected from students to earn full
134 participation points (30) and the maximum quantity of entries possible (39). The maximum number of entries was
135 different from the expected because students had flexibility in how they could earn full participation points, with
136 these assignments and in-class participation. We compared the quantities of entries, actions, and resources per entry
137 per student between choice and text treatments using linear models. Additionally, we compared course performance
138 between the two treatments using students' end-of-semester percentages. All models were run using the lme4
139 package (31) in R (32). The standardized effect size of Hedges' g was used to estimate the magnitude of change for
140 unequal sample sizes (33).

141 Further, we coded each entry for the actions students reported doing and the resources students reported
142 using. Students could report doing multiple actions and using multiple resources per entry; therefore, each entry
143 could have multiple codes. Two researchers used thematic content analysis (34) to iteratively draft and define codes
144 into codebooks that were used to analyze entries for actions (Supplemental Materials S3), resources (Supplemental
145 Materials S4), and websites (Supplemental Materials S5). After creating complete codebooks, two researchers co-
146 coded 10% of the entries and agreed on 83% of the entries. Disparate codes were discussed until agreement was
147 reached and the codebooks were revised accordingly.

148 Further, we examined if students prepared differently based on the grade they earned in the course. We
149 performed MANOVA analysis to examine the relationship between students' entries, actions, or resources based on
150 grade bins (A-F) that students earned at the end of the course. Additionally, we performed ANOVA analysis with
151 post-hoc Tukey tests to examine the relationship between grades within choice and text groups. We used the SPSS
152 package for these statistical analyses with alpha set at 0.05. Further, we qualitatively examined the students' entries
153 for any patterns among grade bins regarding the types of actions students took to prepare for class and the types of
154 resources they used.

155 Results

156 By examining students' entries, we compared how each treatment (choice, text) affected (a) if students
157 prepared for class, (b) the actions students engaged in, and (c) the resources they used to prepare for class. We used

158 these comparisons to also describe how these introductory biology students prepared for classes overall.

159 Additionally, we evaluated if the treatments affected course performance.

160 **Did the treatment affect *if* students prepared for class?**

161 Many students prepared for most of the classes regardless of treatment. There was no significant effect for
162 treatment, $F(1, 150) = 1.83, p = .178$, Hedges' $g = 0.2$ (Figure 1A), on the number of times a student reported
163 preparing for class over the semester between choice ($M = 25, SD = 9.2$) and text ($M = 23, SD = 9.2$). However, a
164 slightly higher percentage of entries were submitted from students in the choice treatment (84% out of the expected
165 number of entries) compared to students in the text treatment (77%). Similarly, only a single entry from the choice
166 treatment reported doing “nothing”; whereas 69 entries (5%) from 17 students (25%) in the text treatment reported
167 doing “nothing” (Table 2). Students were allowed to report doing “nothing” but still got points for the assignment to
168 help mitigate the limitation of relying on self-reported data.

169 [FIGURE 1 HERE]

170 **Did the treatment affect *how* students prepared for class?**

171 We investigated the common actions and resources students reported and compared between the two
172 treatments. Additionally, we examined if students prepared differently based on the grade they earned in the course.

173 ***Actions***

174 Students commonly reported doing multiple actions to prepare for a class. Students in the text treatment
175 reported more actions per entry ($M = 1.7, SD = 0.6$) than students in the choice treatment ($M = 1.4, SD = 0.4$), $F(1,$
176 $150) = 9.4, p = .0026$, Hedges' $g = 0.6$ (Figure 1B). Likewise, students in the text treatment described doing more
177 than one action in 61% of entries compared to only 32% of entries from the choice treatment.

178 Students reported reading most frequently in both treatments with 80% of entries in the choice treatment
179 and 94% of the entries in the text treatment reported reading either by itself or with another action (Table 2).

180 Students in the choice treatment most frequently reported only reading (52%), whereas students in the text treatment
181 reported reading as the only action in 34% of entries, which was second to the combination of reading and taking
182 notes (55%) (Table 3). Similar proportions of entries from the two treatments also reported reading along with
183 watching videos and quizzing (Table 3).

184 [TABLE 2 HERE]

185 There were additional differences in the actions students reported between the two treatment groups
 186 (Tables 2 and 3). Students in the choice treatment more frequently reported watching videos (29% of entries)
 187 compared to students in the text treatment (9%). Other activities—such as quizzing, doing homework assignments,
 188 and working with classmates—were reported at low and similar frequency for both treatments. More entries from
 189 students in the text treatment (56%) reported taking notes than the choice treatment (22%) (Table 2).

190 [TABLE 3 HERE]

191 *Resources*

192 Most often, students used one resource to prepare for each class (Figure 1C). There was no significant
 193 effect for treatment, $F(1, 150) = 0.09, p = .76$, Hedges' $g = 0.1$ (Figure 1C), on the number of resources students
 194 reported using to prepare for each class between choice ($M = 1.20, SD = 0.27$) and text ($M = 1.18, SD = 0.44$).

195 The treatments differed in the types of resources students reported using to prepare for class (Table 4).
 196 Students in the text treatment relied primarily on the assigned textbook passages (90% of entries). Students in the
 197 choice treatment used a wider variety of resources to prepare for class with the most frequent resource being
 198 websites (52%). Websites were almost equally divided between watching a video (29%) or reading text (27%).
 199 Other resources used frequently by students in the choice treatment were the recommended textbook (36%) and
 200 lecture slides (18%).

201 [TABLE 4 HERE]

202 Students in the choice group used several different websites to prepare for class with two general media
 203 being the most common: video and text. YouTube and Khan Academy were the most frequently named websites,
 204 which use videos to present content through combining visual, oral, and written explanations. Other websites that
 205 students used presented content similarly to textbooks (Table 5, “Textbook-like” category) which had mostly text
 206 and some figures. A small proportion of students reported accessing research literature from sites such as nih.gov
 207 and nature.com. The category of “Other” were websites that were infrequently reported, or the details were not
 208 provided.

209 [TABLE 5 HERE]

210 *Grade Bins*

211 We used quantitative analysis to explore the relationships between the choice and text groups based on
212 grades for the number of entries, actions, and resources (descriptive statistics in Table 6, plots in Supplemental
213 Materials S6). None of the relationships were significant (Table 7).

214 [TABLE 6 HERE]

215 [TABLE 7 HERE]

216 However, when we examined the relationship between grades within choice and text groups using
217 ANOVA, we found a significant difference within the text group ($F = 13.296, p = 1.8898E-7$) but not within the
218 choice group ($F = 2.299, p = .066$). The number of entries for students who earned Fs was significantly lower than
219 for all other grades (A: MD = -21.95, $p = 6.7269E-7$, CI (-31.78, -12.13); B: MD = -19.11, $p = 3.6106E-7$, CI (-
220 27.44, 10.79); C: MD = -14.042, $p = .000195$, CI (-22.49, -5.59); D: MD = -12.167, $p = .006$, CI (-21.7, -2.63)). The
221 numbers of entries for students who earned Ds was also significantly lower than for students who earned As (A: MD
222 = -21.952, $p = 6.7269E-7$, CI (-31.78, -12.13)). Statistics for non-significant Tukey test relationships are not shown.

223 We also examined entries organized into grade bins qualitatively but found no consistent and noteworthy
224 themes among the grade bins.

225 **Did the treatment affect course performance?**

226 There was no significant effect for treatment, $F(1, 148) = 0.34, p = .56$, Hedges' $g = 0.1$ (Figure 1D), on
227 students' course grades between choice ($M = 77\%$, $SD = 11.5$) and text ($M = 76\%$, $SD = 13.3$). Similarly, course
228 grades from the complete student populations were also similar between semesters which correspond to the
229 treatment groups.

230 **Discussion & Implications**

231 Instructors want their students to be prepared for class. But little is known about how students prepare for
232 daily class sessions in undergraduate, introductory biology. Further, while several interventions are publicly
233 available and improve student outcomes, some can be expensive, and instructors have been slow to incorporate them
234 into courses. Moreover, little is known about how these interventions affect if and how students prepare for class.
235 Here, we described if and how introductory biology students prepared for class and compared between students who
236 chose for themselves how to prepare or were provided specific textbook reading passages. Looking at course
237 outcomes, we did not detect any significant differences in how students performed in the course between the two

238 treatments. This may be due to both treatments setting an explicit and concrete expectation for students to prepare
239 for class and incentivizing them to do so.

240 Nevertheless, having students prepare for class is an important and meaningful outcome. Here, the students
241 who earned higher grades reported preparing for class significantly more than students who earned lower grades, at
242 least in the text treatment, suggesting that preparing for class is correlated to positive learning outcomes. Similarly,
243 others report that science students who are prepared for class ask more sophisticated questions and perform better on
244 exams (3). Therefore, getting students to prepare for class is important for learning. Below we discuss how our
245 findings, along with relevant literature, support specific recommendations for helping to guide students to prepare
246 for class.

247 Students seemed to work toward meeting the expectation to prepare for class. Here, students reported
248 preparing for 63% of all classes, which is 81% of the classes that they were required to report on to get full points
249 for the assignment (Figure 1A). In other studies that gave students guidance and an expectation to prepare for class,
250 students were more compliant and often had improved learning outcomes (3, 16–18). Conversely, in a study in
251 which the instructors' expectations were not described, less than 30% of students read their textbook chapters
252 completely (5). Others report that first-year college students are unsure about how to prepare for class and may not
253 understand professors' expectations (35). Together, this suggests that instructors' explicit guidance, expectations,
254 and accountability may motivate students to prepare for class. Therefore, we recommend that instructors be explicit
255 about their expectations and incentivize students to prepare for class.

256 Giving students choices on how to prepare may motivate them to prepare for class. Here, students in the
257 choice treatment reported preparing for slightly more classes than students in the text treatment, although this
258 difference was not statistically significant. This increase in preparation could have been mediated through Self-
259 Determination Theory and the Enhanced Affective Engagement (EAE) Hypothesis, which assert that giving students
260 choices increases their attitude, satisfaction, and effort in learning (24, 26, 27). However, studies on the EAE
261 hypothesis show mixed results particularly related to effects on cognitive outcomes. For example, psychology
262 students, who were allowed to make choices about the pacing of their learning and reading tasks, reported being
263 more interested and enjoyed the activities more than students who were not given choices; however, cognitive
264 outcomes did not increase, and some students even had a decrease in cognitive processing (27). Similarly, we did
265 not see any significant differences in overall course performance between the two treatments (Figure 1D). One

266 possible explanation for not detecting a major difference in course performance is that these class preparation
267 assignments were just one factor among many that influence course performance. Nevertheless, when tasked with
268 choosing, students prepared for class more often which is a meaningful outcome. Therefore, we recommend that
269 instructors give students choices for how they should prepare for class to help motivate them to do so. Further
270 research is needed to determine how choices affect students' participation in class and learning at a fine-grained
271 level, similar to what others have done with specific class preparation assignments (16, 17).

272 Providing quality options from which students choose may help students engage more with the resources.
273 Here, students used one resource, regardless of treatment, but students in the text treatment reported doing more
274 actions than students tasked with finding their own resources. This can be interpreted with cognitive load theory
275 which describes people's ability to process information (36). One aspect of cognitive load theory is resource
276 depletion which occurs when the thinking required for one task decreases performance on another because there are
277 not enough cognitive resources available to complete the second task (37). Applied to the current study, this
278 suggests that students in the choice treatment may have used their available cognitive resources to identify the
279 content materials (i.e., resources), so they did not complete as many actions with the material after it was found.
280 Whereas students in the text treatment were able to exert more cognitive resources on engaging with the materials
281 because the materials were provided. Therefore, we recommend that instructors should shoulder this burden of
282 finding multiple resources for students so that students can apply their cognitive resources to understanding the
283 content, unless perhaps a goal of the course or lesson is that students develop information literacy skills of finding
284 credible sources of scientific information.

285 Provided options could reflect students' own choices for resources. Here, students relied on the textbook,
286 even when it was optional, with 36% of choice treatment entries reporting using a textbook. This reliance may stem
287 from being asked to use textbooks in previous coursework. Most of the students in our study were university
288 freshmen or sophomores, and therefore proximal to their high school experience where courses rely heavily on
289 reading textbooks (38, 39). Likewise, college professors often expect students to read textbooks to become familiar
290 with the course material and to enhance learning (10, 40). These experiences may influence students' choice.
291 Furthermore, students commonly used websites that presented information that is similar to textbook formatting.
292 This may be due to a desire for familiarity or simply availability. More work needs to be done to investigate why

293 students choose certain resources. Nevertheless, our evidence suggests that instructors should include a textbook-
294 like option as a resource for students to prepare for class.

295 Another consideration for providing content options for students is the platform or medium in which the
296 information is provided. Traditional media are printed textbooks; however, there are more choices available for
297 students today. For example, students in the choice treatment frequently reported using a website to prepare.
298 Choosing websites to prepare instead of printed textbooks may be due to generational preferences. While
299 Millennials (those born between 1980-1994) prefer printed books for learning, members of Gen Z (those born
300 between 1995-2005) prefer using a screen—videos, games, or apps—for learning (41). The internet may be an
301 important consideration for students because of the ease of access and multiple ways to interact with content.
302 Additionally, with the availability of open access materials, more of these resources may be available at a lower cost
303 than traditional textbooks and appear to be just as effective as traditional textbooks for student learning (5). More
304 research is needed to determine if certain media are more effective than others in helping students prepare for class
305 and learn biological content and which resources students are most motivated to use.

306 **Limitations**

307 The data presented here are self-reported and therefore may not have been a perfect reflection of student's
308 behavior. We tried to mitigate this by making the assignments proximal to the behavior (due before every class), low
309 stakes, for completion points, and gave points for honest reports of doing “nothing.” Future research will focus on
310 collecting data on how much time students spent preparing for class and the effectiveness of different class
311 preparations on in-class engagement and fine-grained learning.

312 **Conclusion**

313 In this study, we examined if and how introductory biology students prepared for class, comparing between
314 two simple interventions. Our findings further support that having students prepare for class is an important goal.
315 Additionally, our findings suggest that giving students the freedom to find and choose their materials may have
316 motivated them to prepare for class but expended cognitive resources leading to less engagement with the materials.
317 Considering how students prepare and having simple assignments to help guide students, that instructors are likely
318 to use, are vital in helping students be ready to engage in class.

319

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406 **Table Legends**

407

408 **Table 1.** Student demographics of consenting students involved in the study. Students in the choice treatment had
409 freedom to choose whatever resources they deemed appropriate to prepare for class and students in the text
410 treatment were assigned specific readings from the textbook to complete before class.

411

412 **Table 2.** Actions students reported when preparing for class comparing between the choice and text treatments. Data
413 are shown as frequency and percentage out of the total entries. Each entry could have multiple actions; therefore,
414 percentages add up to more than 100%.

415

416 **Table 3.** Most common combinations of actions in entries students reported when preparing for class in the choice
417 and text treatments. Data are shown as frequency and percentage out of the total entries.

418

419 **Table 4.** Resources students reported when preparing for class in the choice treatment and text treatment. Data are
420 shown as frequency and percentage out of the total entries. Each entry could have multiple resources; therefore,
421 percentages add up to more than 100%.

422

423 **Table 5.** Websites students in the choice treatment reported using to prepare for class. Each entry (N = 1186) could
424 have multiple websites; therefore, percentages add up to more than 100%.

425

426 **Table 6.** Descriptive statistics for entries, actions, and resources by treatment and the grades students earned in the
427 course.

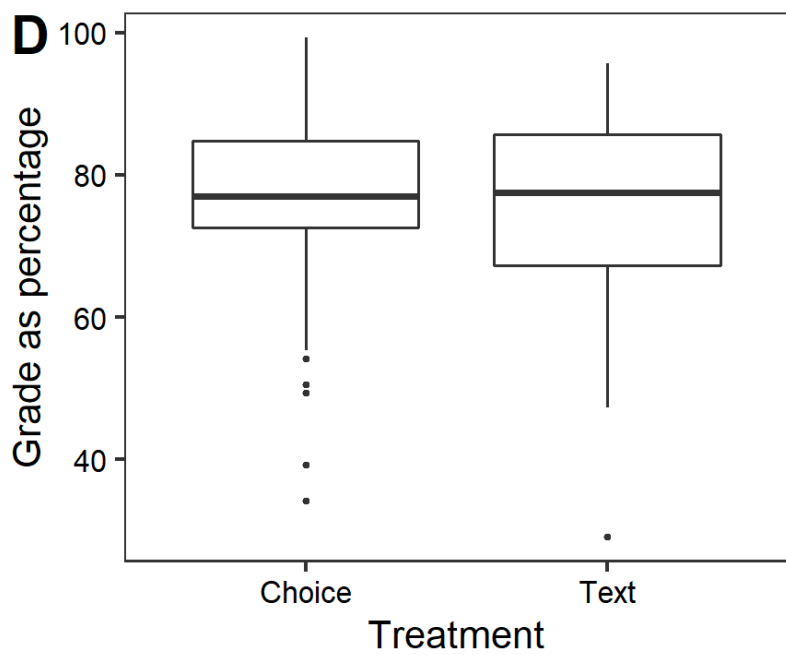
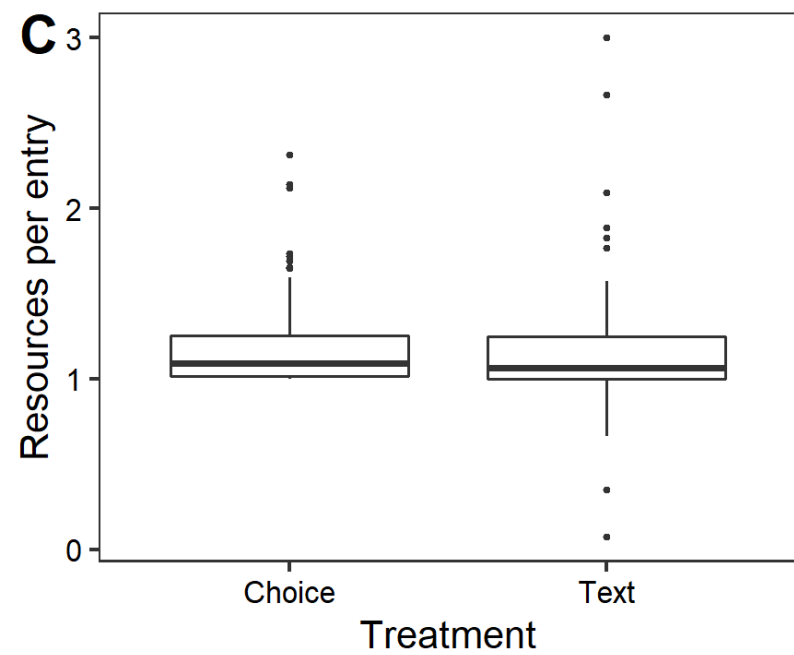
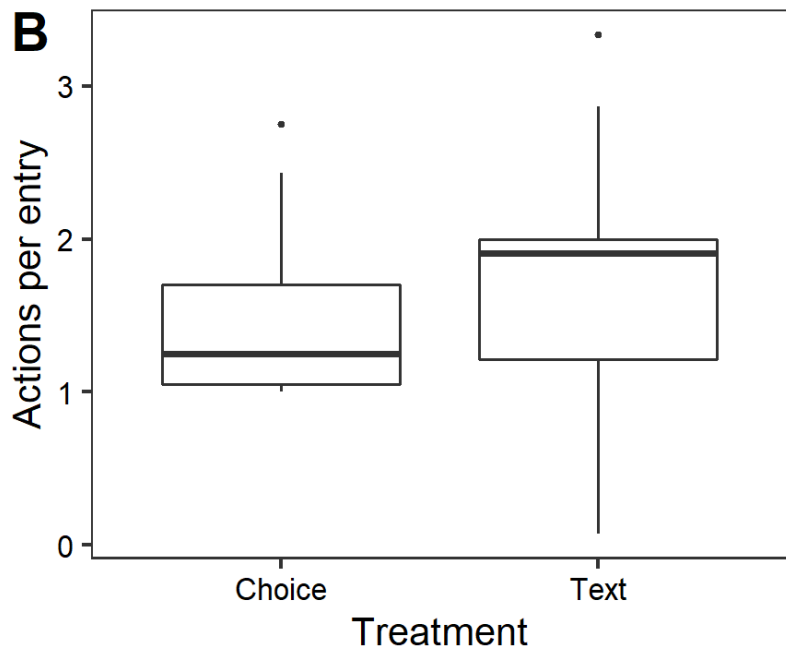
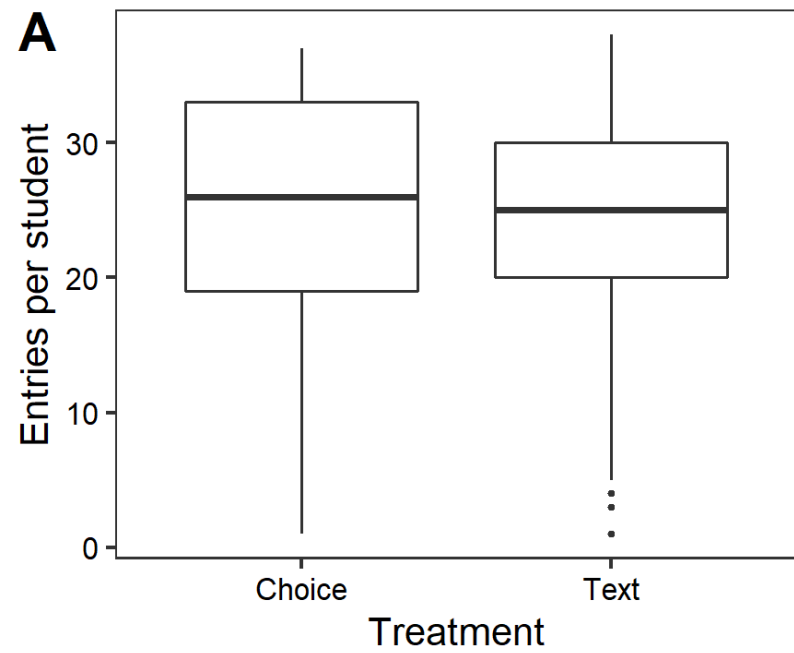
428

429 **Table 7.** MANOVA results for entries, actions, and resources based on grades students earned in the course.

430 **Figure Legends**

431

432 **Figure 1.** Comparison of the two treatments of choice and text for (A) the number of entries submitted per student
433 over the semester, (B) the number of actions students reported per entry, (C) the number of resources students
434 reported per entry, and (D) course performance as overall percentage at the end of the semester.



	Choice % (n)	Text % (n)
N	91	61
Females	69% (63)	80% (49)
Males	31% (28)	20% (12)
18-21 years	82% (75)	84% (51)
22-25 years	12% (11)	13% (8)
26-40 years	5% (5)	3% (2)
White/Non-Hispanic	54% (49)	48% (29)
Hispanic or Latino/Latina	12% (11)	5% (3)
Black or African American/Non-Hispanic	12% (11)	18% (11)
Asian	10% (9)	13% (8)
Multiple Ethnicities	12% (11)	16% (10)
Freshman	36% (33)	31% (19)
Sophomore	29% (26)	43% (26)
Junior	24% (22)	20% (12)
Senior	8% (7)	7% (4)
Graduate or Postbacc	3% (3)	0
First Generation	53% (48)	48% (29)
Transfers	26% (24)	25% (15)
Cum. GPA (SD)	3.0 (0.8)	3.0 (0.7)

Table 2. Actions students reported when preparing for class comparing between the choice and text treatments. Data are shown as frequency and percentage out of the total entries. Each entry could have included multiple actions; therefore, percentages add up to more than 100%.

Action categories	Choice % (n) (N=2298)	Text % (n) (N=1415)
Read	80% (1834)	94% (1330)
Took notes	22% (497)	56% (794)
Watched video	29% (655)	9% (121)
Quizzed self	7% (153)	4% (52)
Other	3% (78)	5% (73)
Nothing	0.04% (1)	5% (69)

Table 3. Most common combinations of actions in entries students reported when preparing for class in the choice and text treatments. Data are shown as frequency and percentage out of the total entries.

Combination categories	Choice % (n) (N=2298)	Text % (n) (N=1415)
Read and Took notes	18% (409)	55% (783)
Read and Watched video	9% (203)	8% (116)
Watched video and Took notes	6% (141)	5% (76)
Read and Quizzed self	6% (130)	4% (50)
Took notes and Quizzed self	3% (68)	3% (47)
Read and Other	2% (57)	4% (59)

Table 4. Resources students reported when preparing for class in the choice treatment and text treatment. Data are shown as frequency and percentage out of the total entries. Each entry could have reported multiple resources; therefore, percentages add up to more than 100%.

Resource categories	Choice % (n) (N = 2298)	Text % (n) (N = 1415)
Textbook	36% (820)	90% (1273)
Websites	52% (1186)	9% (129)
Slides	18% (423)	5% (64)
Other	4% (92)	7% (95)
Notes	2% (47)	5% (69)
Nothing	0.04% (1)	5% (69)

Table 5. Websites students in the choice treatment reported using to prepare for class. Each entry (N = 1186) could have reported multiple websites, therefore percentages add up to more than 100%.

Website categories	Frequency % (n)
YouTube	46% (545)
Textbook-like	30% (357)
Khan Academy	24% (290)
Other	5% (61)
Simulations	3% (40)

Table 6. Descriptive statistics for entries, actions, and resources by treatment and the grades students earned in the course.

Grade	N		Mean # of Entries		Mean # of Actions		Mean # of Resources	
	Choice	Text	Choice	Text	Choice	Text	Choice	Text
A	9	7	32.00	31.29	1.18	1.56	1.06	1.08
B	29	18	26.97	28.44	1.34	1.53	1.16	1.09
C	32	16	23.94	23.38	1.49	1.72	1.23	1.23
D	8	8	22.00	21.5	1.56	2.17	1.31	1.23
F	6	6	21.33	9.33	1.16	1.86	1.08	1.67

Table 7. MANOVA results for entries, actions, and resources based on grades students earned in the course.

	Λ	$F(5, 6)$	p
Entries per grade (A-F)	0.374	2.010	0.210
Actions per grade (A-F)	0.240	3.809	0.067
Resources per grade (A-F)	0.451	1.460	0.326