Identifying the optimal course delivery platform in an undergraduate animal behavior research course

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ABSTRACT: There is a critical need to evaluate pedagogical delivery platforms best suited for undergraduates in the information age. Our goal was to identify the optimum course delivery platform for a basic research course based on student performance and critical thinking scores. Students were expected to plan, conduct, and report on an animal behavior research project of their own design. The course was taught in three different formats: traditional, online, and flipped, over 2 yr by the same instructor at both the University of Florida and Santa Fe College. Student assessments included weekly quizzes, assignments, a written report, a poster presentation, and attendance. We conducted pre- and postassessments using the Cornell Critical Thinking Test (CCTT). Students’ grades differed depending on format delivery and were also different between University of Florida and Santa Fe College students. For students at the University of Florida, quiz grades and poster grades did not differ (P < 0.50) between formats. However, assignment grades (P = 0.04) and report grades (P < 0.001) differed by format and were higher in the flipped and online-only version of the course, compared with traditional. For students at the Santa Fe College, quiz grades (P = 0.71) did not differ, but assignment (P < 0.001), report (P = 0.003), and poster (P < 0.001) grades were higher in the flipped and traditional format of the course. Within the flipped format at the University of Florida, student CCTT scores increased (P < 0.001) between pre- and posttest, whereas the scores within the other formats did not differ. When we compared the magnitude of change between pre- and posttest scores across formats, students at the University of Florida in the flipped format tended (P = 0.060) to have a greater gain than students in the online format. For students at Santa Fe College, there was no difference between pre- and posttest CCTT scores for any format, and the magnitude of change in scores did not differ between formats. Overall, our results suggest that teaching format influences student grades and critical thinking scores. Different effects were seen in different student populations; however, positive effects of the flipped format on student grades were seen at both institutions. In conclusion, flipped format courses may improve learning and critical thinking in an early research-based course.

Key words: animal behavior, critical thinking, flipped classroom, research, undergraduate education

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Transl. Anim. Sci. 2018.2:311–318
doi: 10.1093/tas/txy066

†This research was funded by the National Science Foundation. Division of Undergraduate Education. Award number: 1503322

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Received May 1, 2018.
Accepted June 4, 2018.
INTRODUCTION

The population of students currently enrolled in postsecondary educational institutions is diverse and radically changing how they think and learn (Prensky, 2001, 2005). Traditional education systems have focused on compartmentalized learning where students are expected to learn at the same rate as their peers. Suggested “Information Age” approaches focus on learner-centered education and meeting individual learner needs (Watson and Reigeluth, 2008). Active learning has been suggested for teaching today’s students, focusing on inquiry-based learning (Prince, 2004; McLaughlin et al., 2014). Three primary teaching approaches exist today in higher education: traditional, online, and the emerging flipped format, an active, learner-centered approach where students watch lectures online and participate in learning activities during class time. This approach has been shown to improve student satisfaction, engagement, and course grades over traditional approaches (Critz and Knight, 2013; McLaughlin et al., 2013; Mortensen and Nicholson, 2015). However, others have reported some negative student feedback related to reduced in-person lecture time in flipped classes (Wilson, 2013; Missildine et al., 2013), suggesting that success of different formats may depend on course subject.

There is evidence that the United States is falling behind other countries in science education (Provasnik et al., 2009), suggesting a need to refine teaching methods for inquiry- and research-based courses. Our objectives were to evaluate the effects of delivery formats of a research-based course on student learning outcomes and critical thinking, at both a state university and a community college. We hypothesized that students participating in the flipped class would show improved outcomes and critical thinking, compared with a traditional lecture or asynchronous online-only format, and that effects of different delivery formats may differ between university and college-level student populations.

MATERIALS AND METHODS

Student Population

This study investigated students’ learning achievements through a research-based course, “Wild Discoveries: Zooming into the Scientific Method,” offered at the University of Florida (Gainesville, FL) and Santa Fe College (Gainesville). The course was a one-credit elective offered for 2 yr at both the University of Florida and Santa Fe College (from the Spring semester of 2016 until the Fall semester of 2017). At the University of Florida, the course was taught through the Department of Animal Sciences and offered to first and second year students interested in learning more about the scientific method.

There were a total of 178 students enrolled in the Wild Discoveries course from the University of Florida and a total of 58 students enrolled from Santa Fe College over the 2 yr the course was offered. Student data collection also included gender. Data collection methods were approved through the University of Florida Institutional Review Board.

Course Structure

The Wild Discoveries course was a basic undergraduate research course designed to guide students through the scientific method while they conducted their own research projects from start to finish. Animal behavior was chosen as a focal topic for this course, due to the large portion of animal science and zoo animal program students in our student population and their noted interests. Students were expected to plan, conduct, and report on an animal behavior research project of their own design. Students assessed animal behavior of either domestic or exotic species via either live observation or online web cameras. Besides learning the scientific method, the course presented information on topics including basic principles of animal behavior and ethical issues such as plagiarism and protocols for using animal and human subjects in research.

To investigate the influence of course delivery format, the course was offered according to three different delivery formats: traditional, online, or flipped. At the University of Florida, the course was offered in the traditional format once and the flipped and online formats twice. At Santa Fe College, the course was offered in the traditional and flipped formats twice and the online format once. Student enrollment numbers by format and semester are described in Table 1. The delivery method alternated between formats in consecutive semesters at both schools, dictating how material and assessments were presented (Table 2). The same instructor taught the course in all formats at both schools. In the traditional course, class time consisted of a weekly 50-min period on campus, with material delivered using PowerPoint lectures and quizzes. Assignments and group work were
completed on the students’ own time outside of the class period. In the asynchronous online course, students were expected to watch video lectures, complete quizzes and assignments, and participate in group work online independently. The flipped course included both an asynchronous online component and an in-class face-to-face component. Students were expected to watch online lectures and complete weekly online quizzes. Furthermore, students were expected to complete minimal assignments and group work online. In addition to the online component, students were expected to attend a 50-min face-to-face class period on campus each week. This class time was used to reinforce topics from the previous online lectures and answer any questions the students may have had from the weekly online material (i.e., quizzes, assignments, and group work). Students were also allowed to work on their homework assignments or discuss their research with group members during the face-to-face class time. The online lectures provided through the online and flipped delivery formats were prerecorded at the University of Florida Center for Instructional Technology and Training (CITT) using Mediasite (Sonic Foundry, Madison, WI).

Lectures and material were divided into 14 modules using the online Canvas system (E-learning) with learning objectives and reminders for students within each module. As well, each module included access to quizzes, assignments, and group discussion boards.

**Student Assessments and Outcomes**

For each of these delivery formats, student assessments remained consistent. Course assessment was based on weekly quizzes, weekly assignments, a final written report, a poster presentation of their project, and class attendance. The final grade out of 540 points was calculated based on 120 points from quizzes and assignments, 100 points from the written report, 50 points from the poster presentation, and 150 points from attendance.

There were 12 weekly quizzes. Quiz questions consisted of multiple choice, true and false, and matching. There were 12 weekly homework assignments, which included practice with animal behavior observations, creating and assessing ethograms, data analysis practice, and identifying science project misconducts. Drafts of each of the required components of the research report were submitted as well.

In each format, students were required to complete a semester long research project on the topic of animal behavior. They were divided into small groups of four to five students and were asked to complete the following task: develop a research...
plan, complete a literature review, develop a hypothesis, conduct animal behavior observations, analyze and interpret their findings, write a report on their project, and present their information in a poster format. Animal behavior research was conducted on their own time for each of the three formats.

Attendance was recorded for all delivery formats. For the traditional and flipped formats, weekly attendance was taken during class time. For the online format, attendance was measured through participation in weekly online discussions.

To evaluate the effect of course delivery format on critical thinking, students were evaluated voluntarily using the Cornell Critical Thinking Test (CCTT), level X. This was administered on the first day of class and the final day of class.

Finally, student course evaluations were obtained from the University of Florida students at the end of each semester. Students rated a series of criteria on a scale of 1 to 5, with 1 being poor and 5 being excellent. We summarized descriptive statistics for outcomes for three key criteria: communication of ideas and information, stimulation of interest in course, and facilitation of learning.

**Statistical Analysis**

Student outcome data were summarized by student for each form of assessment (quizzes, assignments, report, and poster). CCTT scores (pre and posttest) were included for analysis if both pre- and posttest scores were completed by the student (complete data sets at the University of Florida: 69 for flipped, 51 for traditional, 9 for online; at Santa Fe College: 16 for flipped, 8 for traditional, 11 for online). Data were analyzed separately by school.

The effects of course delivery format on student outcomes were analyzed using PROC MIXED in SAS (v. 9.4, SAS Institute Inc., Cary, NC). The model included the fixed effects of format and the random effect of student. For data subject to a significant effect of format, the Tukey–Kramer adjustment was used in testing for pairwise differences between formats. For analysis of data from the University of Florida where enrollment was higher, gender and the interaction between gender and format were included in the model as fixed effects.

We evaluated the changes between pre- and posttest CCTT scores within each teaching format using a paired t-test. We also evaluated the effect of format on changes in CCTT scores using the MIXED procedure of SAS, in a model that included format as a fixed effect and pretest scores as a covariate.

All values reported are least squares means. Significance was declared at $P \leq 0.05$, and trends reported at $0.05 < P \leq 0.10$.

**RESULTS**

The Wild Discoveries course was offered for five semesters at both the University of Florida and Santa Fe College from Spring 2016 to Fall 2017. Descriptive data for student attendance by format and semester are shown in Table 3.

| Semester                  | Traditional | Online | Flipped |
|---------------------------|-------------|--------|---------|
| University of Florida (2016) | 97.5 ± 15.5 | 94.3 ± 14.8 | 94.2 ± 23.4 |
| University of Florida (2017) | —          | 98.4 ± 12.5 | 94.5 ± 22.6 |
| Santa Fe College (2016)    | 93.3 ± 25.0 | 81.1 ± 40.5 | 98.1 ± 5.1  |
| Santa Fe College (2017)    | 98.1 ± 23.2 | —      | 97.2 ± 16.6 |

To evaluate the effect of course delivery format on student assessments are presented in Table 4. At the University of Florida, there were no differences between formats for quiz grades, but grades differed by gender, with female students ($n = 140$) having higher grades than males ($n = 38; 85.7\%$ vs. 81.2\%; $P = 0.032$), with no interaction between format and gender ($P = 0.31$). Assignment grades from the University of Florida students differed across formats, with lower grades in the traditional format compared with the flipped format, and students in the online format having intermediate grades. Female students also had higher assignment grades ($92.8\%$ vs. 88.8%; $P = 0.02$), with no interaction between format and gender ($P = 0.99$). Finally, there was a difference between formats for report grades at the University of Florida, with lower grades in the traditional format compared with the flipped and online formats, and no difference between the flipped and online formats. Report grades did not differ by gender ($P = 0.50$). Poster grades were similar across formats but were subject to a gender by format interaction ($P = 0.039$): in the flipped format, female students ($n = 62$) have higher grades than males ($n = 21; 95.1\%$ vs. 91.6%; $P = 0.030$) and no effect of gender in other formats ($P > 0.96$).

The Santa Fe College students had similar quiz grades across formats, but all other assessment grades differed by format (Table 4). Assignment, report, and poster grades were lower in the online format compared with the traditional and flipped
formats, with no difference between traditional and flipped.

We evaluated both changes between pre- and posttest CCTT scores within each format and also compared the magnitude of change in CCTT score across formats. Changes in student critical thinking pre- and posttest scores within formats are described in Table 5. At the University of Florida, CCTT scores increased within the flipped format (Table 5), whereas there was no difference between pre- and posttest scores within the traditional or online format. At Santa Fe College, there was no significant difference within pre- and posttest scores within any format. We also found that the magnitude of change in CCTT scores tended to depend on format \( (P = 0.058) \); students enrolled in flipped format tended to have a greater increase in score compared with online format \( (P = 0.060) \), whereas the magnitude of change in the CCTT score did not differ \( (P > 0.30) \) between flipped and traditional or online and traditional.

The descriptive summaries of student course evaluations from the University of Florida students are shown in Table 6.

**DISCUSSION**

The aim of this study was to evaluate the best delivery platform for an undergraduate animal behavior research-based course. As undergraduate students are changing in how they think and process information, it has been shown that a transformation in pedagogical approaches is needed across many different programs and majors (Prensky, 2001; Watson and Reigeluth, 2008; Benner et al., 2010; Velegol et al., 2015). This transformation includes more student-centered learning, focusing on critical thinking, inquiry-based learning, and application of information, vs. passively relaying facts to students (Benner et al., 2010). Active learning and inquiry-based learning have been found to increase student engagement and learning,

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**Table 4.** Student grades (mean ± SE) for categories of assessments (quizzes, assignments, reports, and posters) in traditional, online, and flipped class formats at the University of Florida and Santa Fe College

| Assessment | Format | SE | \( P \) value |
|------------|--------|----|--------------|
| University of Florida | | | |
| Quizzes | 84.3 | 84.0 | 82.1 | 2.2 | 0.59 |
| Assignments | 88.3^a | 90.9^b | 93.2^b | 1.8 | 0.04 |
| Report | 89.3^a | 96.1^b | 95.6^b | 0.79 | <0.001 |
| Poster | 94.2 | 94.5 | 93.4 | 0.98 | 0.50 |
| Santa Fe College | | | |
| Quizzes | 74.5 | 71.3 | 77.2 | 5.5 | 0.71 |
| Assignments | 95.4^a | 61.2^b | 91.2^b | 2.5 | <0.001 |
| Report | 84.5^a | 58.3^b | 88.7^b | 7.0 | 0.003 |
| Poster | 91.4^a | 58.3^b | 92.4^b | 6.3 | <0.001 |

\( ^a,b \) Different superscripts denote significant differences between formats \( (P < 0.05) \) for each assessment.

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**Table 5.** CCTT (level X) pre- and posttest scores of students\(^*\) enrolled in traditional, online, and flipped format at the University of Florida and Santa Fe College

| Assessment | Pretest | Posttest | SE | \( P \) value |
|------------|---------|----------|----|--------------|
| University of Florida | | | | |
| Traditional | 52.25 | 51.82 | 0.84 | 0.61 |
| Online | 43.89 | 46.78 | 1.63 | 0.11 |
| Flipped | 48.74 | 52.28 | 0.94 | <0.001 |
| Santa Fe College | | | | |
| Traditional | 47.75 | 49.25 | 1.78 | 0.43 |
| Online | 43.64 | 46.36 | 2.37 | 0.28 |
| Flipped | 47.13 | 48.06 | 1.87 | 0.62 |

\( ^* \)University of Florida students: \( n = 69 \) for flipped, 51 for traditional, 9 for online; Santa Fe College students: \( n = 16 \) for flipped, 8 for traditional, 11 for online.

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**Table 6.** Faculty course evaluations\(^*\) (mean ± SD) for key criteria of interest, summarized across all semesters by format, from the University of Florida

| Description of course objectives and assignments | Traditional | Online | Flipped |
|--------------------------------------------------|-------------|--------|---------|
| Communication of ideas and information | 4.61 ± 0.73 | 4.47 ± 0.92 | 4.81 ± 0.45 |
| Stimulation of interest in course | 4.64 ± 0.72 | 4.62 ± 0.56 | 4.76 ± 0.48 |
| Facilitation of learning | 4.77 ± 0.60 | 4.62 ± 0.56 | 4.71 ± 0.60 |
| Overall assessment of instructor | 4.72 ± 0.70 | 4.69 ± 0.54 | 4.92 ± 0.29 |

\( ^* \)Scores are based on a 1 to 5 scale. 1 = poor, 2 = below average, 3 = average, 4 = above average, 5 = excellent.
and when application of knowledge and material is completed in class, teachers are available to be facilitators and aid in their learning (Prince, 2004; Watson and Riegluth, 2008; Chi, 2009).

In addition to ongoing challenges of adapting course delivery platforms to meet the needs of today’s science-focused students, we need to involve undergraduates in research earlier in their collegiate career. Therefore, the focal course for this study was developed with the intended aim of involving undergraduate students in the scientific method and having students conduct their own research. We proposed that in completing a research project of their own design, students would be fully exposed to the scientific method.

A concern with the flipped format is the potential for low class attendance if lecture information can be found online (Foldnes, 2017). Class attendance is positively associated with academic achievement in both traditional lecture-based classes (Crede et al., 2010; Schneider and Preckel, 2017) and the flipped classroom (Foldnes, 2017). We found no difference in student attendance between formats, which is consistent with previous findings in flipped compared with traditional format classes (Deslauriers et al., 2011; McLaughlin et al., 2014; Mortensen and Nicholson, 2015).

The results from the University of Florida students show that while format may not matter for some assessments, it was significantly different in others. When there was a difference, in the case of assignment and report grades, the flipped and online formats led to higher grades than the traditional format. These results may suggest that these formats facilitate greater learning and are best suited for first and second year students in an early-based research course. Both online and flipped classes provided access to the same online lectures, which students could watch as many times as needed on their own time. This may partially explain why students performed better. Mortensen and Nicholson (2015) found that students in a flipped format class watched lectures multiple times (e.g., 1.9 views/student for the first lecture of the course). The flipped format also provided more time for students to interact with each other and the instructor during class meeting times. It has been shown that when students are informed of the purpose of the flipped classroom and how it works and why it is important, students are more engaged (Betihavas et al., 2016).

Our findings are consistent with numerous other studies that have shown that courses taught in the flipped format have shown improved student grades and achievement compared with the same course taught in a traditional format (McLaughlin et al., 2014; Mortensen and Nicholson, 2015; Peterson, 2016). However, empirical data on student learning and achievement between teaching formats are limited (O’Flaherty and Phillips, 2015). Some studies have shown that there are no differences in student grades or achievement when a course was taught in different formats (Galway et al., 2014; Harrington et al., 2015; Morgan et al., 2015). However, there has been limited previous comparison between all three delivery methods: traditional, online, and flipped.

A meta-analysis of K-12 education showed that blended learning, same as flipped format, was more effective than either face-to-face or online format (Means et al., 2009). In a statistical literacy course, Gundlach et al. (2015) compared the efficacy of the three delivery formats taught within a single semester and found that most results were very similar between formats and showed no differences. The only differences they found between formats were an increase in perceived easiness in traditional format vs. the online format (Gundlach et al., 2015). Somenarain et al. (2010) evaluated different delivery formats in a medical terminology course and found no significant difference in course grades and student satisfaction between the online and flipped courses; however, it is important to note that each format was delivered by a different instructor. To our knowledge, the present study is the first to evaluate the efficacy of different delivery methods in a basic research-based course. Furthermore, the design of this study allowed assessing different delivery methods over the course of multiple semesters, with consistency of instruction.

The format appeared to play a large role with the students from Santa Fe College, especially with regard to the online course. Overall, the online format resulted in the lowest grades in all categories. Feedback from students indicated the online format was the least preferred delivery mechanism. It is possible that this may reflect differences in expectations or previous experiences of students enrolled in smaller colleges. However, our limited enrollment of students in the online course offered at Santa Fe College restricts our ability to generalize these results. A study by Zavarella (2008), showed completion rates for a community college mathematics course were higher in traditional formats with 80% completion vs. online courses with only 61% completion. This study reported 70% of students in the online section withdrew because of problems associated with the online component of the course.
Another study on college-level students in an online course found that gender, academic readiness, and number of online courses enrolled had a significant effect on how well students did (Aragon and Johnson, 2008). Finally, Jaggars and Bailey (2010) completed a meta-analysis on the effectiveness of fully online courses for college students and suggest that online learning may have negative effects on academically underprepared students. Our results are in agreement with Aragon and Johnson (2008) and Jaggars and Bailey (2010) that college-level students may be unprepared for an online course.

Interestingly, we found some effects of gender on student grades at the University of Florida. For the most part, these findings were independent of format. However, in the case of poster scores, female students received higher grades in the flipped format only. It is important to note that our study population involved a greater percentage of females than males (78.7% vs. 21.3%), which was representative of the gender demographics at the departmental level [86.3% vs. 13.7%, female vs. male enrollment in the Department of Animal Sciences across 2016–2017, UF IFAS (2018) Enrollment Data] which we expect may influence this result.

Finally, we found that there was a gain in critical thinking within the flipped format, but not within the traditional or online format from the University of Florida students. This is consistent with results from Mortensen and Nicholson (2015) who showed increased critical thinking from pre- to posttest scores in the flipped format. Furthermore, the magnitude of change in the CCTT tended to be greater in the flipped format compared with online, with the traditional format having intermediate outcomes. These results suggested students may not be engaging themselves in critical thinking and inquiry-based learning as much in an online course compared with a more formal classroom setting. Perhaps classroom interaction, whether traditional or flipped, is needed to encourage and inspire student’s critical thinking. DeRuisseau (2016) also found a greater gain in critical thinking in a flipped vs. formal science course at a liberal arts college, based on questions that required higher order thinking using Blooms Taxonomy. Other studies have demonstrated active learning can increase critical thinking (Prince, 2004; Watson and Reigeluth, 2008).

University course evaluations are often used to get feedback from the students on the course. Our descriptive summary of course evaluations suggests that all formats were numerically similar and ranked “Above Average.” Others have found no differences between the traditional and flipped courses with regard to course evaluations (Simpson and Richards, 2015).

Overall, our results suggest that teaching format can influence student grades and critical thinking scores whether at a 4-yr university or college. Our results demonstrated at the university level the flipped and online formats led to higher grades than the traditional format. These results may suggest these formats better facilitate learning from this group of students. Furthermore, the results from the CCTT increased in the flipped format compared with the other formats, suggesting that some aspect of in-class learning may help to increase critical thinking. Overall, this study demonstrated that the flipped format of teaching may produce more desirable outcomes for students partaking in a research-based course.

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