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Flipping the anatomy classroom: a comparative analysis of 16-week and 8-week courses in a community college

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Using flipped teaching modality, a student-centered approach, in community college courses remains an understudied area. This study explored the effectiveness of unflipped (UF), partially flipped (PF), and fully flipped (FF) teaching formats within the confines of an accelerated 8-week Introduction to Human Anatomy course at a community college. The purpose of this study was to examine flipped teaching in an accelerated anatomy course by comparing final examination scores between the UF, PF, and FF modalities, compare the effectiveness of flipped teaching between a regular (16-week) and an accelerated anatomy course, evaluate the effect of different teaching modalities on male and female students between a regular and an accelerated course; and examine UF, PF, and FF among the above-median and the below-median students. Students in the FF sections were required to read relevant chapter(s) in the textbook and review slides before class. Students in the PF sections were required to read the textbook and slides for 25% of the chapters. All students took the same final exams and similar section exams. Final exam scores were higher in the regular 16-week course than in the 8-week course for UF ($p = 0.0219$) and PF ($p = 0.0183$) modalities. The 16-week course had higher final examination scores ($p = 0.0492$; $n = 65$) than the 8-week course. Male students scored lower in the 8-week FF course (49.42 ± 13.72) than in the 8-week PF ($p = 0.006$) and 16-week FF ($p = 0.0008$) formats and also compared to female students in the 8-week FF course ($p = 0.0121$). Above-median students in the 8-week course had significantly lower scores in the FF modality (71.35 ± 7.01) compared to PF (80.92 ± 5.30) ($p = 0.009$). Below-median students in the 8-week course had lower scores in the FF modality (52.25 ± 11.48) compared to UF ($p = 0.0113$) and PF ($p = 0.04$). In conclusion, FF in a 16-week anatomy course resulted in higher final exam scores than in the 8-week course. The 8-week FF format affected male student scores. Both above- and below-median groups experienced similar effects when exposed to FF within the accelerated course. Further investigations are essential to inform the refinement of flipped teaching methodologies in community colleges, particularly in the context of accelerated courses.

KEYWORDS

gross anatomy education, undergraduate education, flipped classroom, student success, course duration

1 Introduction

Evidence-based pedagogies for student engagement and learning are crucial in supporting community colleges. Active learning strategies, such as group discussions, problem-solving activities, and peer teaching, have been found to improve student engagement and knowledge retention (Freeman et al., 2014; Faucette, 2023; Loyens et al., 2023). The flipped classroom model is one such approach that embodies active learning and enhances student achievement and engagement (Talbert, 2017; Dehghanzadeh and Jafaraghaee, 2018; Doğan et al., 2023).

The flipped teaching method is an instructional approach that reimagines the traditional classroom setup by relocating lectures outside the classroom. Instead, in-class time is reallocated to foster student-centered activities, thereby facilitating a more profound comprehension of the subject matter (Al-Samarraie et al., 2020; Strelan et al., 2020; Özbay and Çınar, 2021; Baig and Yadegaridehkordi, 2023). The flipped classroom consists of two fundamental components: pre- and in-class phases. During the pre-class stage, students acquire foundational knowledge through pre-recorded lecture videos and assigned readings. This phase is pivotal for establishing the fundamental concepts that serve as a springboard for the subsequent in-class activities. In contrast, the in-class segment incorporates a diverse range of activities, including succinct review sessions in the form of mini-lectures, self-assessment exercises, valuable instructor feedback, and a deliberate emphasis on delving into advanced content (Lo and Hew, 2019; Al-Samarraie et al., 2020). These in-class activities are designed to actively engage students and promote a deeper understanding of the subject (Subari, 2017; Talbert, 2017; Cevikbas and Kaiser, 2020; Gopalan et al., 2020; Mojtahedi et al., 2020; Namaziandost et al., 2020; Kapur et al., 2022).

The evidence supporting the efficacy of flipped teaching over traditional methods continues to grow (Pierce and Fox, 2012; Freeman et al., 2014; Ozudogru and Aksu, 2020; Jdaitawi, 2021). By transferring lecture content to independent learning spaces outside the classroom, students are expected to assume greater responsibility for mastering fundamental concepts. This shift provides flexibility and enhances self-efficacy (Herreid and Schiller, 2013; Tune et al., 2013). As a result of this relocation of lectures, class time can be capitalized toward fostering peer and instructor interactions and facilitating formative assessments. Consequently, students gain more opportunities to engage in in-depth discussions and are repeatedly exposed to the course material. The incorporation of individual and group assessments allows students to test and apply their knowledge, which in turn contributes to improved learning outcomes and test scores (Li et al., 2020; Wei et al., 2020; Halpin and Gopalan, 2021; Sivarajan et al., 2021).

One common hurdle in adopting flipped teaching is students' initial resistance to this new modality (Lo and Hew, 2019). Due to the COVID-19 pandemic, this resistance has decreased somewhat (Asad and Srivastava, 2020). Flipped teaching demands a consistent time commitment throughout the semester, encouraging students to avoid cramming for major exams. Additionally, student motivation can be challenging because flipped instruction requires more preparation for class and participation in formative assessments compared to the traditional lecture method (Gopalan et al., 2020).

The outbreak of COVID-19 precipitated an abrupt shift to online teaching for instructors worldwide, with some opting for the flipped teaching approach (Morton, 2020; Roy et al., 2020; Yoo et al., 2020; McWatt, 2021). The adoption of flipped instruction during this transition was likely due to its ability to allow students to review lecture recordings at their own pace in an asynchronous format. This flexibility enabled students to schedule their learning around external commitments and minimize distractions (Dove, 2013; McWatt, 2021; Riedl et al., 2021).

Faculty encounter two primary concerns when implementing flipped teaching: the time investment and student evaluations. The initial stages of adopting flipped instruction demand a substantial time commitment, often necessitating a temporary shift from other responsibilities including scholarship and service. Furthermore, course evaluations may fluctuate since flipped teaching represents a novel approach for many students (Hornstein, 2017). Instructors may oppose this teaching method due to unfamiliarity with its implementation and the initial preparation required (Bove and Conklin, 2019). To address the challenge of transitioning an entire curriculum at once, instructors can begin by flipping a small portion of the content, known as a partial flip (PF). As they develop more flipped content, they can eventually apply this method to the entire course, referred to as a full flip (FF) (Kostka and Marshall, 2018). In contrast, the traditional lecture method will henceforth be referred to as 'unflipped' (UF).

Notably, there is a paucity of evidence regarding the effectiveness of flipped teaching at community colleges, particularly in the Science, Technology, Engineering, and Mathematics (STEM) fields. Community colleges are known for their diverse student populations, with individuals of various ages, ethnicities, and backgrounds as well as additional responsibilities such as employment and family commitments. This diversity can enrich the learning environment, but it also presents challenges in adapting teaching methods to cater to a wide array of needs and experiences (Karp et al., 2010; Dougherty, 2016). Community colleges often serve students with diverse levels of educational preparedness. Some students possess a strong academic foundation, while others may require remedial coursework (Jenkins et al., 2014). Many community college students face financial constraints and often juggle work, family, and college, which could result in an increased workload, affecting their ability to dedicate time to coursework (Twigg, 2009; Shapiro et al., 2015). Addressing these varying needs while maintaining academic rigor is a unique challenge. Given its flexibility, flipped teaching is expected to be well-suited for community college students (Dove, 2013; Riedl et al., 2021). Students will be able to access pre-class content at their available times and as frequently as it takes to become familiar with the content. Active learning strategies employed during class time to engage students would reinforce their understanding of the subject further. A comprehensive grasp of student learning preferences is indispensable for optimizing anatomy instruction (Cullinane and Barry, 2023). The investigation of these preferences remains an ongoing endeavor, as they can vary due to a spectrum of factors encompassing cultural backgrounds, individuality, age, and academic preparation (Holtbrügge and Mohr, 2010). Central to this concept is the modality preference, which underscores the significance of employing an individual's preferred learning approach to enhance educational outcomes (Lodge et al., 2016). Flipped teaching allows students to be exposed to the content early on and this priming is beneficial in learning the content at a deeper level. Active learning strategies employed during class time to engage students would reinforce their

understanding of the subject further. Teachers being able to spend more time with students in the flipped teaching modality will be able to assess students' abilities and will use appropriate tools to enhance student engagement. Moreover, students are exposed to content multiple times and go through several formative assessments in the flipped pedagogy which may help them determine their learning styles.

Research on learning styles based on gender has yielded inconclusive results. While Idrizi et al. (2023) suggested gender differences in learning styles, with females preferring read/write and males favoring kinesthetic styles, another study by Voyer and Voyer (2014) highlighted a female advantage in learning. These disparate findings challenge stereotypical beliefs that females excel in language and males in math and science (Halpern et al., 2011). This study explored whether flipped teaching had any effect particularly on male versus female students.

The existing evidence on the benefits of flipped teaching for students who are earning better grades versus those barely passing is inconclusive (Wozny et al., 2018; Gopalan et al., 2020; Herrero and Quiroga, 2020). Gopalan et al. observed improvement in both upper and lower-median groups, while Herrero & Quiroga's findings suggested that below-median students derived greater benefits from this instructional approach. Conversely, Wozny et al. reported positive impacts on above-median students (Wozny et al., 2018). The conflicting results highlight the ambiguity surrounding the effects of flipped teaching on distinct student groups within a course. Acknowledging this uncertainty, our study aimed to contribute to the understanding by investigating the impact of flipped teaching on students performing above and below the median levels in their classes. This examination encompassed three instructional modalities: UF, partially PF, and FF. Through this exploration, we aimed to provide additional insights into the varied effects of flipped teaching across different student performance brackets.

Students have many course options to enroll in, such as accelerated programs, expedited degree completion, and/or accommodation for schedule conflicts especially at the community college level. Eames et al. (2018) studied examination scores between an accelerated and traditional accountant program and found no significant difference between the two. Thus, a well-designed accelerated course can increase the quantity of well-qualified accountants (Eames et al., 2018). There are reports indicating increased stress levels when the course length is shortened (Green, 2020).

1.1 Study goals

The objectives of this study were to: (1) examine flipped teaching at a community college in an accelerated (8-week) anatomy course by comparing final examination scores between the UF, PF, and FF modalities; (2) compare the effectiveness of flipped teaching in the form of final examination scores between a regular (16-week) and an accelerated anatomy course at a community college setting; (3) evaluate the effect of different modalities on male and female students between a regular and an accelerated anatomy course; and (4) examine the three teaching modalities, UF, PF, and FF, among the above-median and the below-median students. It was hypothesized that students experiencing FF in the 16-week course would perform better than their peers in the 8-week course since there is a greater ratio of time to tests. Also, in the regular course, the content would be distributed over a more extended period of time which could make students feel less stressed and achieve higher scores in the flipped teaching modality. Flipped teaching, as it exposes students to content multiple times through pre-class and in-class activities, was expected to increase academic performance in both the above- and below-median students. It was speculated that both male and female students would benefit from FF, particularly the regular 16-week course (Gross et al., 2015; Yan et al., 2018; Gopalan et al., 2020). Yan et al. reported that female students were more efficient than their male counterparts in a UF course. This study also showed that the motivation of the male students was enhanced by the FF method (Yan et al., 2018). Gross et al. compared student performance between the FF method and found that female students benefited more than male students (Gross et al., 2015).

2 Materials and methods

This study was conducted at a Community College immediately before the COVID pandemic. A total of 197 students participated in the study, and all were instructed by the same faculty member. Participants self-selected to enroll in an Introduction to Human Anatomy taught by the same professor. There was no prerequisites for this class. There was no exclusion of students. All students enrolled in the course were included in this study. There were no repeat students in any of the classes studied. A comparison of final examination scores between the traditional UF versus PF and FF sections of an 8-week *Introduction to Human Anatomy* course was made (Figure 1). Next, a comparison of FF between the accelerated 8-week and the regular 16-week course was carried out (Figure 2). This study was approved by the Southern Illinois University Edwardsville Institutional Review Board. An exempt status was received for the protocol (Protocol # 112).

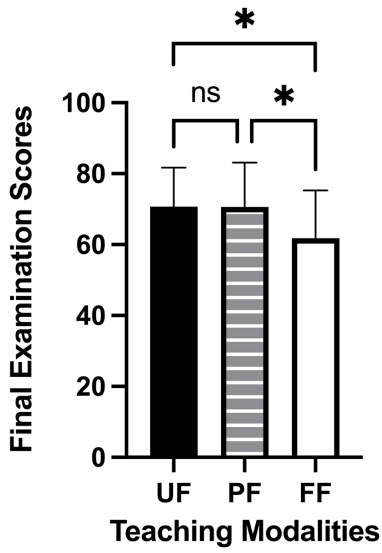

FIGURE 1
A comparison was made between UF, PF, and FF teaching modalities using the final examination scores of each of these courses. UF ($N = 41$), PF ($N = 62$), and FF course ($N = 29$) in an 8-week course using one-way analysis of variance. *$p < 0.05$. UF, unflipped; PF, partially flipped, and FF, fully flipped.

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For UF classes, traditional lectures were delivered by the professor, slide by slide. Students were not required to do anything prior to coming to class. For PF and FF classes, students were required to read assigned pages in the textbook and study slides before coming to class.

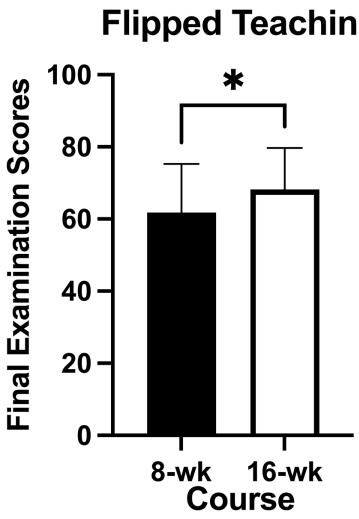

FIGURE 2
A comparison was made between a regular semester of FF and an accelerated FF course. Comparison of the final examination scores from one section of an 8-week FF course ($N = 29$) with the two sections of a 16-week FF course ($N = 65$) using student t-test. *$p < 0.05$. FF, fully flipped.

Various activities, ranging from Q&A mini-lectures, small group problem-solving, and games, were implemented during class. The UF course was an 8-week accelerated course that was taught in the Spring of 2018 in two sections. The PF course was also an 8-week accelerated course that was taught in the Fall of 2018 as two separate sections. Both 8-week and 16-week FF courses were taught in Spring 2019 (Tables 1, 2).

All courses were model-based and used a systemic approach. The 8-week courses included weekly examinations and laboratory practice. Exams were bi-weekly for the 16-week class (Tables 1, 2). The examinations in all courses contained multiple-choice and short-answer questions. Except for the short answer questions, which were at the application, analysis, or synthesis level of Bloom's taxonomy, the multiple-choice questions were at the factual or comprehension levels. Students were not allowed to use any resources or collaborate with other students during the exam. The instructor proctored all the examinations throughout the entire period. The weekly examinations in the accelerated course and the bi-weekly examinations in the regular course were tested out of 50 points, whereas the final examination in both formats was worth 100 points. The same final examination was used between sections and was conducted during their scheduled class time. Students were not given copies of their final exam back to prevent leakage of questions but were encouraged to make appointments to review their performance. Moreover, every course had pre-lecture quizzes and pre-class assignments, except for the UF 8-week course. Furthermore, the instructor graded students for participation and extra credits in all classes. The total synchronous lecture and lab

TABLE 1 Course details between the regular 16-week and accelerated 8-week semesters.

8-week course curriculum				
			PF flipped content	
Week	Content covered	Examinations	Section 1	Section 2
1	Chemistry, Cell, Tissues	1	–	–
2	Heart, Respiratory System, Blood Vessels	2	–	–
3	Vascular, Digestive, and Lymphatic Systems	3	–	Flipped
4	Endocrine, Reproductive, and Urinary Systems.	4	–	Flipped
5	Skin and Nervous System I: Central Nervous System	5	Flipped	–
6	Nervous System II: Somatic and Autonomic Nervous Systems, Skeletal System I: Axial Skeleton	6	Flipped	–
7	Skeletal System II: Appendicular Skeleton, Articulations, Muscle Tissues, and Muscular System	7	–	–
8	Review	Comprehensive	–	–

16-week course curriculum		
Week	Content covered	Examinations
1–2	Chemistry, Cell, Tissues	1
3–4	Heart, Respiratory System, Blood Vessels	2
5–6	Vascular, Digestive, and Lymphatic Systems	3
7–8	Endocrine, Reproductive, and Urinary Systems.	4
9–10	Skin and Nervous System I: Central Nervous System	5
11–12	Nervous System II: Somatic and Autonomic Nervous Systems, Skeletal System I: Axial Skeleton	6
13–14	Skeletal System II: Appendicular Skeleton, Articulations, Muscle Tissues, and Muscular System	7
15–16	Review	Comprehensive

TABLE 2 Teaching Modalities, Course Characteristics, and Student Demographics.

Modality	Course details			Student details				
	Description	Examinations	Time between examinations	Section 1	Section 2	Male	Female	Total
8-week UF	A traditionally taught course in an accelerated format	7 Examinations and 1 Comprehensive Examinations	1 week	22	19	11	30	41
8-week PF	A course taught with components of flipped teaching for two exams	7 Examinations and 1 Comprehensive Examinations	1 week	30	32	14	48	62
8-week FF	A fully flipped course taught in an accelerated format	7 Examinations and 1 Comprehensive Examinations	1 week	29	-	6	23	29
16-week FF	A fully flipped course taught in a traditional 16-week format	7 Examinations and 1 Comprehensive Examinations	2 weeks	37	28	30	35	65

time per week for the UF and PF classes was 6 h and 20 min. The 8-week FF class had synchronous lectures and lab for 6 h and 20 min. The 16-week FF course had a synchronous lecture and lab time of 3 h and 10 min per week. Thus, the 8-week and 16-week course laboratory times were equated in the overall course configuration.

2.1 The 8-week accelerated course

The PF modality contained 25% flipped teaching, whereas the remaining 75% was taught in the UF style. To avoid the potential for the bias of having the flipped content be different in difficulty than the UF content (in the PF portion of the study), the topics flipped in one section were intentionally selected to be different from the second section. For example, the first section flipped the nervous system portion (tested in examinations five and six), whereas the second section flipped digestive, reproductive, and renal systems, which were covered in examinations three and four (Table 1). In addition, the scores of the PF portion of the semester were compared with the matching UF content.

All students in the flipped teaching design had access to PowerPoint slides (Windows 8, Redmond, WA) with voice annotation. Assigned readings and slides were posted on Canvas by week and were accessible to students the Friday before the week each system was to be discussed for asynchronous studying. A quiz that the students were expected to take ensured not only their participation but also to screen if students struggled with any particular content. Students were expected to independently review the content before class, participate in the discussion, and engage in learning activities. These learning activities include question-and-answer sessions, as well as informal group activities and quizzes during the synchronous teaching portion. Students in the flipped courses were informed that there would be no re-lecturing of the flipped content and they should ask questions by emailing the instructor before or at the beginning of the synchronous component, prior to engaging in learning activities. Students in the UF portion received slides with voice annotation on the day of lecture and a pop quiz during class time.

2.2 Statistical analysis

G* power (version 3.1) analysis was used to verify that the sample size was sufficiently large enough to provide at least 80% Power in the proposed statistical analysis. Specifically, the parameters used to conduct the power analysis for calculating the desired sample size included: Power = 80%, alpha = 5%, and a moderate to moderately large effect size of partial eta squared = 0.15. This analysis indicated that the desired sample size under these conditions, taking into account the time series experimental design as well as the four possible treatment combinations, was 116 subjects. The larger sample size used in this study (197 students) allowed for the detection of smaller effect sizes.

A one-way analysis of variance (ANOVA) was used to compare the student performance between UF, PF, and FF teaching formats in an 8-week course, where the student groups were the row factor and teaching modalities were the column factor. A post-hoc student *t*-test was used to compare (1) the final examination scores of the two sections of the PF; (2) flipped portions against UF sections, and (3) the test scores between the eight- and 16-week courses. A two-way ANOVA was used to compare sex differences (row factor) in the final examination scores between the UF, PF, and FF groups (column factor), as well as the comparison of the above- and below-median groups (row factor). The values were significantly different if the *p*-value was less than 0.05%. GraphPad Prism version 9.2 (GraphPad Software, San Diego, CA) was utilized in all of these analyses and the preparation of histograms (Figures 1–5). The values are presented as mean and standard deviation.

3 Results

3.1 Comparison of teaching modalities in the accelerated (8-week course)

A comparison was made between UF, PF, and FF using the final examination scores of each of these courses. Two sections each of UF ($N = 41$) and PF ($N = 62$) were compared with one section of the FF

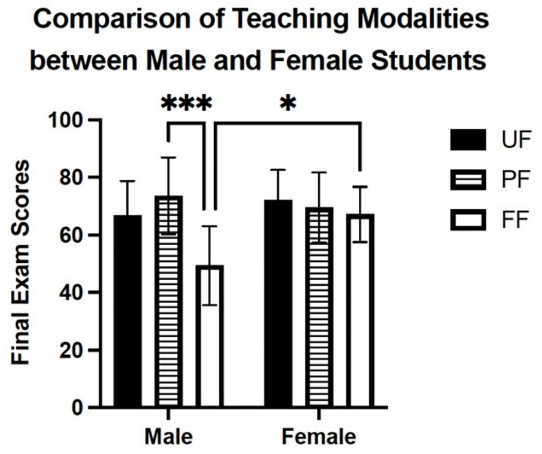

FIGURE 3
The effect of teaching modality on male versus female students was examined using an accelerated 8-week course. Comparison of final examination scores from the 8-week UF, PF, and FF courses between male (UF: $N = 11$, PF: $N = 14$, and FF: $N = 6$) and female students (UF: $N = 31$, PF: $N = 38$, and FF: $N = 14$) using two-way analysis of variance. *$p < 0.05$; ***$p < 0.001$. UF, unflipped; PF, partially flipped; and FF, fully flipped.

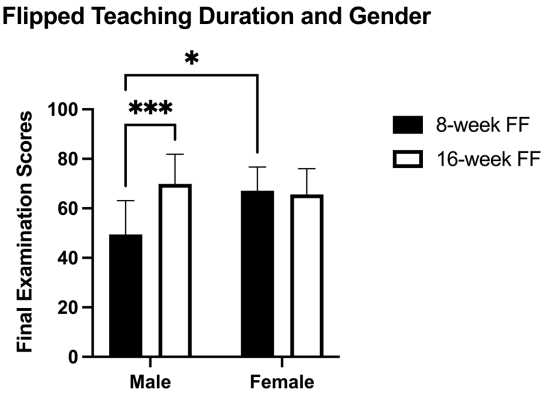

FIGURE 4
A comparison of the final examination scores between two FFs, 8-week and 16-week, revealed that the scores from the 16-week course were significantly greater among male students (male $N = 6$; female $N = 14$) versus 16-week FF (male $N = 30$ and female $N = 19$) using two-way analysis of variance. *$p < 0.05$; ***$p < 0.001$. FF, fully flipped.

course ($N = 29$) of an 8-week accelerated course. Post-hoc analyses revealed no significant difference in the final examination scores between the UF (70.71 ± 11.03) and PF (70.64 ± 12.52) groups ($p = 0.999$). Both UF ($p = 0.022$) and PF ($p = 0.018$) scores were significantly greater than in the FF group [61.80 ± 13.48; $F(2,111) = 4.387$; Figure 1].

The scores of the PF portion of the semester were studied to determine whether they would be similar or different from the matching UF content. The weekly examination scores from PF within section 1 (examinations three and four; 34.83 ± 8.412) were compared with the examination scores of the same content from the UF section (section 2; 36.28 ± 7.652). Similarly, the weekly examination scores from section 2 (examinations 5 and 6; 32.84 ± 7.212) were compared with the same content from the UF (section 1; 34.38 ± 7.559) portion of the 8-week accelerated course and noted that they were not significantly different (section 1 $p = 0.3739$ and section 2 $p = 0.72$).

3.2 Accelerated (8-week) versus regular (16-week) FF

A comparison was made between a regular semester of FF and an accelerated FF course. When the final examination scores from one 8-week FF course (61.80 ± 13.48, $N = 29$) were compared with two 16-week FF sections (68.22 ± 11.48, $N = 65$), the scores in the 16-week course were significantly higher ($p = 0.0492$; Figure 2).

3.3 Effect of teaching modalities on male and female students

The effect of teaching modality on male versus female students was examined using an accelerated 8-week course. When the final examination scores were compared among the three teaching modalities, UF, PF, and FF, the scores from the FF (49.42 ± 13.72, $N = 6$) were significantly lower compared to the PF group (73.61 ± 13.38, $N = 14$) among male students [$F(2,108 = 5.316)$; $p = 0.006$]. The FF scores in the male student group were not significantly different from the UF (70.71 ± 11.03, $N = 11$). On the other hand, female students performed similarly in all three modalities (UF 72.07 ± 10.6; $N = 31$, PF 69.55 ± 12.19; $N = 38$, and FF 67.11 ± 9.6; $N = 14$), as there was no significant difference between the three teaching methods tested. Male students' final examination scores from the FF group were significantly lower compared to the female FF group ($p = 0.0194$; Figure 3).

A comparison of the final examination scores between two FFs, 8-week and 16-week, revealed that the scores from the 16-week course were significantly greater among male students (69.87 ± 12.01, $N = 30$) than the accelerated 8-week FF [49.42 ± 13.72; $N = 6$; $F(1,65) = 11.67$; $p = 0.0011$]. Female students, on the other hand, performed similarly in both the 8-week (67.12 ± 9.60, $N = 14$, $p = 0.0121$) and 16-week FF (65.63 ± 10.37, $N = 19$, Figure 4).

3.4 Student performance among the above- and below-median students

The final examination scores were compared between the above- and below-median students in the three teaching modalities of 8-week courses, UF, PF, and FF. Although the interaction between the above- and below-median groups and the teaching modalities was not significant [$F(1,65) = 0.04361$; $p = 0.8352$], the row factor [$F(1,65) = 82.86$; $p < 0.0001$] and the column factor [$F(1,65) = 9.2$; $p = 0.0034$] were significantly different. Turkey's multiple comparison test revealed that the above-median students' performance in the FF (71.35 ± 7.01, $N = 10$) was significantly lower compared to PF (80.92 ± 5.30, $N = 26$, $p < 0.01$) whereas the below-median students' performance in the FF (52.25 ± 11.48, $N = 10$) was significantly lower compared to the UF and PF portion (UF 61.93 ± 6.45; $N = 21$; PF 60.36 ± 8.48; $N = 26$; $p < 0.05$). Overall, the student performance in FF was the

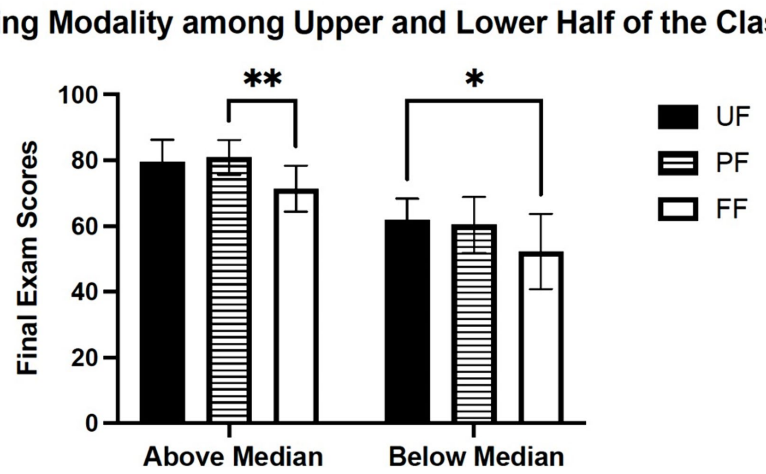

FIGURE 5
The final examination scores were compared between the above- and below-median students in the three teaching modalities of 8-week courses, UF, PF, and FF. Comparison of final examination scores of different teaching modalities of the accelerated 8-week courses between the above- and below-median students using two-way analysis of variance. *$p < 0.05$; **$p < 0.01$. UF, unflipped; PF, partially flipped; and FF, fully flipped.

lowest among all the teaching methods tested in the accelerated course (Figure 5).

A comparison of student performance in their final examinations of an 8-week versus a 16-week FF course was made after separating the students into above- and below-median groups. Although there was a slightly higher in student scores in the 16-week FF (above median 77.16 ± 5.8; below-median 58.92 ± 7.93; $N = 25$) compared to the 8-week (above median 71.35 ± 7.01; and below-median 52.25 ± 11.48; $N = 10$), these numbers were not significantly different.

4 Discussion

Traditional approaches, such as didactic lectures and dissection-based laboratory sessions, have prevailed thus far in the educational approach of anatomical sciences, but continued testing of new techniques is essential to advancing student-centered teaching modalities in the future (Salinas-Alvarez et al., 2021). This study attempted to examine student performance between the UF, PF, and FF formats in an accelerated 8-week *Introduction to Human Anatomy* course at a community college. A comparison of above- and below-median groups, as well as male and female students was made. Additionally, the final examination scores in the accelerated 8-week semester were evaluated with those of the regular 16-week FF courses to analyze the course length's impact on student performance.

As shown in Figure 1, the scores in the accelerated 8-week FF were significantly lower than both UF and PF. Since it was an accelerated course, the students may not have had the time to complete expected pre-class activities in order to be prepared for the in-class engagement. Since this course was an accelerated course, the limited time for the students to interact with the flipped teaching modality appears to be a challenge. In a condensed version of a course, the study material is generally more overwhelming to handle in between scheduled classes.

More likely, any performance difference while comparing the effectiveness of flipped teaching in the form of final examination scores between a regular (16-week) and an accelerated anatomy course was due to the fact that the students in the regular format had more contact hours with the instructor, which helped them learn the content better than in the accelerated course, where there was limited time between the instructor and the students (bi-weekly instead of weekly assessments). In contrast to the findings from this study, Barral et al. reported improved scores with flipped teaching in their accelerated *Introductory Biology* course (Barral et al., 2018). Reimer et al. also reported flipped teaching to promote student performance in the 8-week summer organic chemistry course (Reimer et al., 2021). It must be noted that both studies were conducted at four-year institutions, whereas the current study tested community college students. Whether the discrepancy in the findings is due to the difference in the student populations is unknown. Community colleges typically have a unique student population where students have outside responsibilities such as employment, family commitments, and a greater range of diversity in terms of age (Karp et al., 2010; Dougherty, 2016). The considerable amount of out-of-class time required in this teaching method could be one reason for the lower scores observed in the 8-week FF course. Any absence due to increased commitment could affect student performance since they are more likely to be unfamiliar with the concepts.

When comparing PF between two sections of the 8-week courses, it was intentionally designed to select content from different units of the course, such as the nervous system in one section versus the digestive, renal, and reproductive topics in the second section, to avoid assuming that the selected unit was the most difficult or the easiest compared to the rest of the content. Irrespective of the content flipped, PF was not effective. Partial flipping in this study design occurred either in the middle (3rd and 4th examinations) or at the end (5th and 6th examinations) of the semester. It is shown that the students adjust to their courses at the very beginning of the semester, and it is rather difficult to introduce new modes in the latter part of the semester (Syofyan and Siwi, 2018). Students are often preoccupied by due dates for papers, presentations, and tests,

which may lead some to not fully focus on readjusting to the course in the middle or the end of the semester (Gerrard et al., 2017). On a positive note, this study suggests that instructors can add elements of the flipped classroom without negatively impacting the students since PF was equally effective as UF. Educators must carefully plan the implementation of flipped components in their courses.

Based on the results from this study, the ideal FF approach for community college students, especially male students, was the regular 16-week rather than the accelerated 8-week course (Figures 3, 4). The success of the 16-week format could be that the content was spaced out, made available throughout the semester, and delivered in more digestible chunks. Perhaps, students felt less constricted by time to process information and become familiar with the teaching method, which then encouraged more interaction in class. A study by Romaker (2021) using a regular semester reported that male students at the community college exhibited higher passing rates in the flipped teaching design when compared to traditional learning (Romaker, 2021). The opposite effect was seen in this study. Flipped teaching design requires structured independent study time to be successful and students in the accelerated course have limited time to prepare for the in-class work (Heijstra and Sigurðardóttir, 2018). The number of male students in the current study was small in the 8-week ($N = 6$) compared to the 16-week FF course ($N = 30$). The small number in the 8-week FF course might have contributed to the lower scores, especially if one or two students were not as strong as the rest. Female students performed similarly in the 8-week and 16-week FF, suggesting that they were able to adapt to both the accelerated 8-week and the regular 16-week courses (Mašić et al., 2021). Whether the higher number of female students compared to male students in every section of the 8-week accelerated course may have influenced these findings is unknown. The 16-week FF course had a similar distribution of male and female students, and hence the results were comparable in terms of their performance (Table 2).

When the class was separated into upper and lower halves and analyzed the modality that was effective for these two groups, it was apparent that FF in an 8-week course was not well received by both halves of the class. Flipped teaching implementation occurred for the first time in this course. The comfort level of the instructor may help improve the situation in the future with necessary adjustments. Students in an accelerated 8-week class require substantially more organization to embrace active and innovative learning in the classroom (Barral et al., 2018).

Several factors can affect student performance without a selection process or prerequisite requirements, including varied student abilities, different backgrounds, and motivation. Some students may need more foundational knowledge to succeed, making it challenging for the teacher to meet the needs of all students. Specific teaching strategies may provide additional support to ensure that all students have the opportunity to succeed. Flipped teaching could be one of those, but more work is needed, especially at the community college level.

4.1 Limitations of the study

The limitations of this study were: (1) the number of sections for the different learning modalities. The 8-week FF only had one section, while the 8-week UF and PF, as well as the 16-week FF, had two sections; (2) the absence of 16-week courses for UF and PF; (3) the male sample size which was noticeably smaller in the 8-week course than the female students; (4) Although the final exams were identical, the scores between sections might reflect differences in the student body due to many factors that are beyond our capability to analyze. Having a more uniform sample size would strengthen the findings of this study and yield more reliable conclusions.

5 Conclusion

The findings from this study suggest that FF in a regular 16-week course increased examination scores compared to the accelerated 8-week course. Male students struggled with the accelerated 8-week FF course compared to the 16-week semester. Thus, the length of the course appears to be a key factor for students to absorb course content where the regular 16-week course is more effective than the accelerated course for flipped teaching. Both above- and below-median groups of students were negatively affected by FF in the accelerated course. Female students scored similarly in all modalities tested, suggesting that they could handle different modalities equally well. PF did not negatively impact student performance, which suggests that educators can add elements of the flipped classroom wherever it is appropriate for their courses. There are many contexts in which the flipped classroom could be easier and more practical to implement.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Southern Illinois University Edwardsville Institutional Review Board. An exempt status was received for the protocol (Protocol # 112). The studies were conducted in accordance with the local legislation and institutional requirements. The ethics committee/institutional review board waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin because an exempt status was received for the protocol.

Author contributions

CG: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. EB: Writing – original draft, Writing – review & editing. SD: Writing – original draft, Writing – review & editing. K-LN: Investigation, Methodology, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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