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## The flipped-classroom approach to teaching horizontal strabismus in ophthalmology residency: a multicentered randomized controlled study

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### Abstract

**BACKGROUND**—The flipped-classroom involves watching prerecorded lectures at home followed by group learning exercises within the classroom. This study compares the flipped classroom approach with the traditional classroom for teaching horizontal strabismus didactics in ophthalmology residency.

**METHODS**—In this multicenter, randomized controlled survey study from October 2017 to July 2018, 110 ophthalmology residents were taught esotropia and exotropia sequentially, randomized by order and classroom style. Flipped classroom participants were assigned a preclass video lecture prior to the in-class case-based activity. The traditional classroom included a preparatory reading assignment and an in-person lecture. Residents completed three identical 5-question assessments (pretest, post-test, and 3-month retention) and surveys for each classroom. The primary outcome measured residents' preferences for classroom styles; the secondary outcome compared knowledge acquisition.

**RESULTS**—In our study cohort, the flipped classroom resulted in greater at-home preparation than the traditional classroom ( $P=0.001$ ) and was preferred by 33 of 53 residents (62%); 45 of 53 (85%) wished to see the flipped classroom used at least 25% of the time. The exotropia flipped classroom scored higher than traditional classroom on the pretest (3.71/5 [74%] vs 2.87/5 [57%];

$P < 0.001$ ) and post-test (4.53/5 [91%] vs 4.13/5 [83%];  $P = 0.01$ ) but not the 3-month retention test (3.53/5 [71%] vs 3.37/5 [67%];  $P = 0.48$ ). The esotropia classroom styles did not differ on pre- or post-test but demonstrated higher scores for the traditional classroom at 3-month retention (3.43/5 [69%] vs 2.92/5 [58%];  $P = 0.03$ ). Advantages cited for flipped classroom include being interactive and engaging while incentivizing better classroom preparation.

**CONCLUSIONS**—The flipped classroom method was received favorably by trainees and may complement traditional methods of teaching.

In the United States, resident education in ophthalmology is largely based on a traditional lecture format. In the flipped-classroom approach, residents familiarize themselves with new material prior to class, typically with online lectures, and classroom time is devoted to discussion-based cases. The flipped classroom fits well into Bloom's taxonomy, a basic framework for developing educational curriculum whereby lower hierarchical learning and comprehension is followed by higher level analysis, synthesis, and evaluation.<sup>1</sup> Classroom time in the flipped-classroom model is dedicated toward achieving these higher cognitive tasks. Undergraduate and medical students were found to benefit from the flipped classroom through increased motivation and learning.<sup>2–7</sup> Freeman and colleagues<sup>8</sup> also found that the flipped-classroom approach improved test scores and reduced failure rates compared to traditional lectures. The flipped classroom has had mixed but overall favorable outcomes in graduate medical education, including emergency medicine,<sup>9–11</sup> anesthesia,<sup>12</sup> critical care,<sup>13</sup> and internal medicine.<sup>14,15</sup> Greater exploration of the flipped-classroom approach in other graduate medical education specialties is needed.

In our previously published pilot study,<sup>16</sup> 40 ophthalmology residents from 4 residency programs demonstrated higher test scores in the flipped classroom relative to traditional lecture in exotropia but not esotropia subject matter, with a significant preference for the flipped classroom format among post-graduate year (PGY) 3–4 residents. The present study aimed to build on the pilot study, randomizing 11 US ophthalmology residency programs to both classroom styles, with the addition of a 3-month post-test to evaluate long-term knowledge retention. We hypothesized that ophthalmology residents would favor the flipped-classroom style over traditional lecture, with possible additional benefits to knowledge acquisition and retention.

## Participants and Methods

Based on the pilot study, we estimated a minimum sample size of 25, with 80% power to detect a 0.8-point difference in content test scores between the two classroom styles.<sup>16</sup> All ophthalmology residents (PGY-2, PGY-3, and PGY-4) from 11 departments were invited to voluntarily participate in two educational sessions. Participating ophthalmology residency programs included the University of Washington, Duke University, University of Oklahoma, University of California at Davis, University of California at San Francisco, Oregon Health & Science University (OHSU), University of Rochester, University of Miami, University of Cincinnati, University of Iowa, and Virginia Commonwealth University. Institutional review board approval was obtained or exempted at all participating institutions. Informed consent was not required; however, all residents were informed that study participation was voluntary. The senior author (MTC) used a computerized random-number generator to

randomize each institution based on the order and format (traditional or flipped) of two topics (esotropia and exotropia), such that each instructor taught one topic in the traditional lecture format and the other topic in the flipped classroom format 1–3 weeks later to the same group of residents (Figure 1).

## Intervention

The standardized curricula for esotropia and exotropia were developed as previously described.<sup>16</sup>

Three days prior to their classroom session, residents were emailed the preclass preparation instructions. Those preparing for the flipped classroom were instructed to download and watch the 30-minute PowerPoint (Microsoft Corporation, Redmond, WA) lecture independently. Those preparing for the traditional classroom were instructed to read the relevant chapters from the textbook Basic and Clinical Science Course (BCSC, American Academy of Ophthalmology) using their preferred method (computer, mobile device, or book).

For the flipped classroom setting, participants took a pretest on their own then formed groups of 2–3, including preferably a junior and senior resident along with a medical student (if present). For the next 35 minutes, participants were instructed to work together through Prezi (a presentation software analogous to PowerPoint; San Francisco, CA)<sup>17</sup> presentation cases, committing to group answers to the clinical questions in Prezi before advancing. These cases contained no overlap with their home PowerPoint presentations. Suggested times for each case were included. The fellowship-trained faculty instructor circulated around the classroom to answer questions and engage residents in active discussion. After the allotted time, participants were given the post-test to complete individually. Afterward, the faculty instructor facilitated an interactive group discussion (9 minutes) to review answers and key concepts. Finally, the residents completed an anonymous Likert-scale survey (Figure 1).

For the traditional classroom, residents took a pretest and then received a 44-minute standardized PowerPoint lecture delivered in-person by an attending pediatric ophthalmologist at each respective institution. All instructors were given the freedom to present in whatever style they preferred in order to simulate real-life variation in the traditional lecture format. Residents completed the post-test and the anonymous Likert-scale survey (Figure 1) individually after the lecture.

## Outcomes Measured

Participants were asked to complete both a written (Likert-scale) survey in the classroom and an additional online survey afterward (Catalyst WebQ, University of Washington, Seattle, WA). Residents were asked to rate their preference for traditional versus flipped classroom format, the effectiveness of preparation and classroom material, and the advantages and disadvantages of the flipped classroom format in free text form. Residents were asked to estimate the percentage of time that they would like to see the flipped-classroom approach implemented (0%, 25%, 50%, 75%, or 100%). They were asked to give their opinion regarding the theoretical effectiveness of the flipped classroom in teaching

other subspecialty ophthalmology topics. Demographics were not requested to maintain anonymity. All surveys were voluntary and all survey questions were previously trialed in the pilot.<sup>16</sup>

Participants were assessed for knowledge three times for each course: prior to (pretest), immediately after (post-test), and 3 months after the course (retention; Figure 1). In order to standardize testing, all 5-minute assessments consisted of the same previously piloted<sup>16</sup> 5 Ophthalmic Knowledge Assessment Program–style questions created by the authors (MTC, LBE, TLY, NGG). Although there may have been bias toward improved scores with repetition, the authors felt that uniform questions provided more comparable paired analysis.

### Analysis of Outcomes

The primary outcome was the residents' preference for classroom format, measured by online survey results among those who attended both classrooms. The Likert-style written survey responses were analyzed to assess their level of preparation and educational experience. A Cronbach alpha statistic was applied to two sets of similar questions for internal consistency, and the average was used in the final analysis. The secondary outcome was whether the flipped classroom increased knowledge acquisition compared to the traditional classroom, measured by assessing the pre-, post-, and 3-month retention scores with a paired *t* test that matched individuals with their study identification number. Any missing data or mismatched identification numbers were excluded. Additional sub-analyses were performed to measure the impact of pre-class preparation on score results. The  $\chi^2$  or the Fisher exact test was used for all comparisons of categorical data; *t* tests, for all other continuous data. A two-sided *P* value of 0.05 or less was considered statistically significant. All analyses used IBM SPSS Statistics for Windows, version 26 (2019; IBM Corp, Armonk, NY).

## Results

Based on post-test participation, a total of 110 participants took part in the flipped classroom and 103 in the traditional classroom between October 2017 and January 2018. Combined total Likert survey participation was 207 (97%), including 106 after the esotropia course and 101 after the exotropia course. A total of 74 of 110 residents (67%) responded to the online survey after both classrooms were completed (28 PGY-2, 28 PGY-3, 18 PGY-4). For long-term retention testing analysis, 23/110 (21%) residents were excluded (missing study identification numbers in 21/23 [91%] and unavailable residents in 2/23 [9%]). The remaining 87/110 (79%) residents underwent final 3-month follow-up content testing between January and July 2018.

### Likert Survey Results

The Cronbach statistics for equivalent test questions on preparatory and classroom work were 0.99 and 0.96, respectively, demonstrating good agreement. Among all surveys, 156 of 207 (75% of residents) completed at least 50% of the assigned preparatory work prior to either classroom (PowerPoint video lecture for flipped classroom; BCSC reading for traditional classroom).

Participants prepared more for the flipped classroom (92/105 [86%] prepared 50%) compared to the traditional classroom (66/102 [65%] prepared 50%;  $P=0.001$ ; 95% CI, 0.10–0.32). For all comers, more preparation led to greater satisfaction with the preparatory work ( $P<0.001$ ), but satisfaction with the in-class activity was not affected by preparation (Table 1). Of residents who completed 50% preparation, no differences between classroom style satisfaction scores for either preparatory work or in-class experience were seen (Table 1).

### Electronic Survey Results

Of 74 residents who responded to the online survey, 53 (72%) attended both classrooms. Of these 53, 33 (62%) preferred the flipped-classroom style, and 45 (85%) wished to see the flipped classroom format used at least 25% of the time. Even among those who preferred the traditional classroom format, 12 of 20 (60%) wanted to see the flipped-classroom approach implemented at least 25% of the time. The flipped classroom was preferred among all levels of trainees (11/21 [52%] PGY2, 14/23 [61%] PGY3, and 8/9 [89%] PGY4 residents;  $P=0.08$  comparing levels; Figure 2), with higher level residents demonstrating a greater preference for the flipped classroom.

Advantages of the flipped classroom include its interactive and engaging approach ( $n=27$ ), encouragement of residents to prepare beforehand ( $n=9$ ), and better retention due to the interactive format ( $n=7$ ). Disadvantages include its limited utility if residents did not prepare ( $n=13$ ), more required preparatory work ( $n=13$ ), and varying quality of classroom experiences ( $n=10$ ; Table 2). Most residents (77%) agreed or strongly agreed that the flipped-classroom style would be appropriate for all subspecialties within ophthalmology, without preferences ( $P=0.87$ ).

### Content Testing

Content testing results are shown in Figure 3. For the exotropia course, flipped-classroom participants scored higher than those in the traditional classroom for the pretest ( $P<0.001$ ; 95% CI, 0.38–1.30) and post-test ( $P=0.01$ ; 95% CI, 0.09–0.71) but not the 3-month retention test ( $P=0.48$ ; 95% CI –0.30 to 0.63). There were no differences in improvement from pre- to post-test ( $P=0.08$ ; 95% CI, –0.85 to 0.05). For the esotropia course, there were no differences between classroom styles in pre- ( $P=0.07$ ; 95% CI, –0.84 to 0.04) and post-tests ( $P=0.25$ ; 95% CI, 0.13 to 0.50), but residents in the flipped classroom scored lower than traditional classroom for the 3-month retention test ( $P=0.03$ ; 95% CI, –0.97 to –0.06). For the esotropia course, the flipped classrooms saw a greater improvement from pre- to post-test compared with traditional classrooms ( $P=0.01$ ; 95% CI, 0.11–0.94). Of the 76 residents who completed 50% preparation for the exotropia course, the flipped-classroom scores exceeded those of the traditional classroom for the pre- (3.79/5 [76%] vs 2.95 [59%];  $P=0.001$ ) and post-tests (4.64/5 [93%] vs 4.16/5 [83%];  $P=0.008$ ), but not 3-month retention (3.60/5 [72%] vs 3.15/5 [63%];  $P=0.17$ ). Of the 23 residents who completed 25% preparation, there were no longer differences between flipped and traditional classrooms with regard to pretest (3.00/5 [60%] vs 2.69/5 [54%];  $P=0.65$ ) and post-test (3.71/5 [74%] vs 4.13/5 [83%];  $P=0.30$ ). The 3-month retention also did not differ between classroom styles (3.43/5 [69%] vs 3.29/5 [66%];  $P=0.79$ ). For esotropia, greater

preparation (50%) did not improve test scores for the flipped classroom relative to the traditional classroom pre-test (2.90/5 [58%] vs 3.25/5 [65%],  $P=0.16$ ) or post-test (3.73/5 [75%] vs 3.48/5 [70%];  $P=0.17$ ). However, the 3-month retention test no longer favored the traditional classroom (3.04/5[61%] vs 3.15[63%],  $P=0.73$ ).

When broken down by year of training, PGY3s favored exotropia flipped classroom over traditional classroom on the pre-test (4.12/5[82%] vs 3.00/5[60%],  $P<0.001$ ) and post-test (4.81/5[96%] vs 4.17/5[83%];  $P=0.03$ ). PGY3s favored traditional esotropia classroom over flipped classroom for the pre-test (3.47/5 [69%] vs 2.70/5 [54%];  $P=0.03$ ), but exhibited a greater improvement from pre- to post-test for the esotropia flipped classroom compared to the traditional classroom ( $P=0.001$ ; 95% CI, 0.47–1.80). Other differences, when divided by year of training, did not reach statistical significance.

### Protocol Deviations

Residents were allotted 10 minutes instead of 5 minutes for their traditional (esotropia) quiz at one site, traditional (exotropia) quizzes at two additional sites, and all quizzes at a fourth site. In addition, one site conducted their knowledge retention test at 9 months post-classroom instead of 3 months.

Secondary analysis was performed after excluding above programs that deviated from the time allotted for quizzes. After exclusions, the exotropia post-test still favored the flipped classroom but was no longer statistically significant, likely due to the smaller sample size (4.53/5 [91%] vs 4.28/5 [86%];  $P=0.16$ ;  $n=83$ ). All other results were essentially unchanged with similar  $P$  values to analyses without exclusions (data not shown).

### Discussion

In this multicentered, randomized controlled study evaluating the flipped classroom approach to teaching horizontal strabismus, more ophthalmology residents (62%) preferred the flipped classroom to the traditional classroom, and 85% wanted to see the flipped-classroom approach implemented for at least 25% of their didactics. Even among those who favored the traditional approach, 60% preferred flipped classroom for at least 25% of their training. Most residents (77%) felt that the flipped-classroom style would be theoretically appropriate for all ophthalmology subspecialties. Our study confirms prior work in graduate medical education that found higher learner satisfaction with the flipped classroom.<sup>11,14</sup> Higher satisfaction may not only suggest increased learning, but it may improve rate of attendance when applied to a real-life setting.

Content testing performance was mixed, with the flipped classroom outperforming the traditional classroom in the pre- and post-test ( $P=0.01$ ) for the exotropia but not the esotropia coursework, whereas 3-month retention testing favored the traditional classroom. Differences in content testing results by subject matter in the present study align with our pilot study<sup>16</sup> and have been described in other medical specialties.<sup>12,15</sup> We hypothesize that in spite of a uniform curriculum development process, variation in curriculum efficacy may contribute to these findings. For example, a particularly effective esotropia traditional lecture may skew results in favor of the traditional lecture compared to the flipped-classroom



format. Nonetheless, absolute differences in test scores were small (<1 question out of 5), suggesting that the flipped classroom format resulted in similar outcomes to the traditional classroom with respect to content testing.

When separated by year of training, each year had a greater preference for the flipped classroom over the traditional classroom, with that proportion increasing with seniority. Residents indicated from survey responses that teaching material to their peers helped solidify their own understanding, which could help explain the higher favorability among senior residents. However, this preference did not reflect a clear advantage of the flipped classroom over traditional classroom in content testing that increased by year of training; instead, PGY3s seemed to have the greatest advantage (although absolute differences were small). The authors believe that all residency training levels can benefit from the peer engagement and interactive nature of flipped-classroom learning.<sup>18,19</sup>

Residents were more inclined to complete the flipped-classroom preparatory work than traditional classroom work (86% vs 65% completed 50% of the preclass material). The authors see this difference as one of the many advantages of the flipped-classroom approach; it seems less likely that this difference is exclusively responsible for all flipped-classroom favorability, given the overwhelming literature in favor of active learning approaches, even without preparatory activity.<sup>8</sup> The rate of completion may have been even greater had residents been given more than 3 days to complete the activity. Although the flipped classroom depends more on completion of preparatory work to be effective compared with the traditional classroom, implementation of the flipped-classroom approach in conjunction with traditional teaching methods can achieve success within the time constraints of busy residents. A varied approach to didactics education could therefore benefit more learners.

Study limitations include a potential survey response bias; residents with a greater preference for the flipped classroom format may be more likely to respond to the survey. We were also unable to account for site-specific variation, such as prior flipped-classroom experience among instructors and participants, including 4 sites that participated in the pilot.<sup>16</sup> Some residents from those sites may have recalled prior test questions, although randomization and paired internal assessments should have prevented bias. The efficacy of the large-group discussion that took place at the end of the flipped-classroom session was not independently assessed. Lastly, although quizzes are a measurable marker for knowledge acquisition, it remains unclear whether the short quizzes in this study captured the possible clinical decision-making skills gained by the flipped classroom experience. Study strengths included its paired study design, randomization of topics and institutions, and large number of institutions with a high response rate in surveys and testing. Results were well-aligned with those of the pilot study,<sup>16</sup> confirming the conclusion that the flipped-classroom style should be considered for some ophthalmology residency didactics. Future areas to explore include evaluating best practices for flipped classrooms to enhance knowledge retention, creating more comprehensive knowledge assessments, and utilizing flipped classroom through remote learning.



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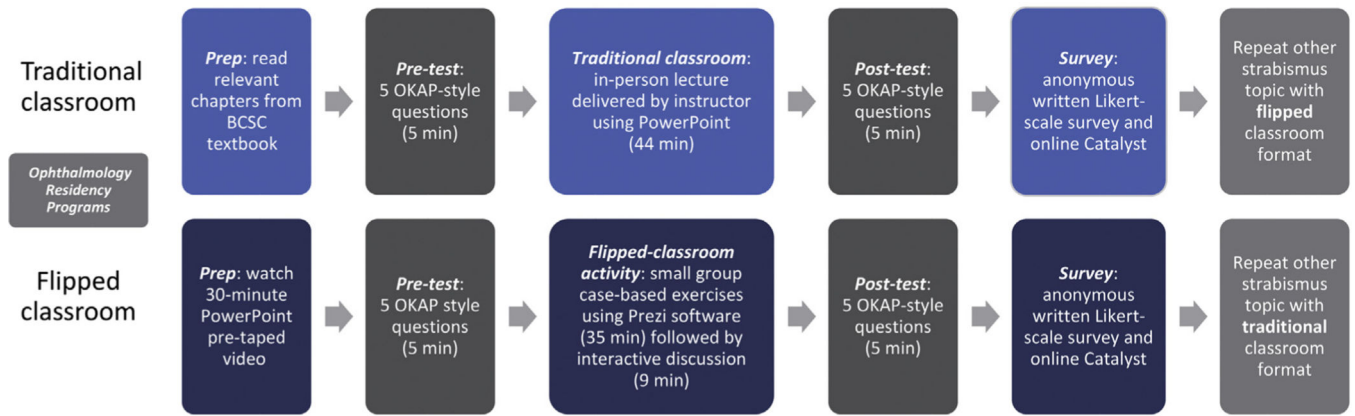
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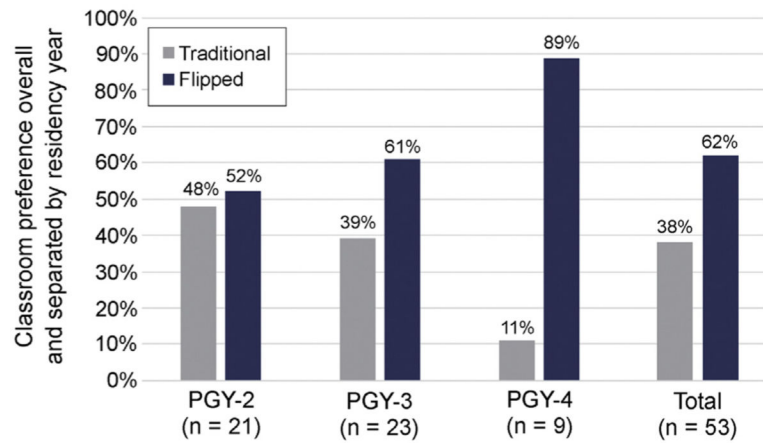
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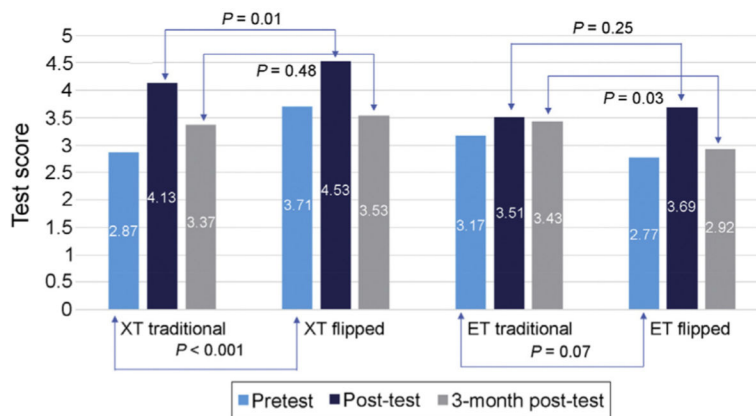
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**FIG 1.** Schematic of the flipped classroom and traditional classroom protocol. Each institution was randomized by topic (esotropia and exotropia), classroom style (flipped classroom and traditional classroom), and order.



**FIG 2.** Preference for traditional or flipped classroom overall and separated by residency year based on anonymous online surveys administered following both classroom styles. Separated by year of training, there was a majority preference for the flipped classroom among all levels of trainees, with higher-level residents demonstrating a greater preference for the flipped classroom than lower-level residents ( $P = 0.08$ ).

**FIG 3.**

Content test results for flipped versus traditional classroom. For exotropia, participants in the flipped classroom scored higher than the traditional classroom for the pre- and post-tests but not for the 3-month post-test. For esotropia, the two classroom styles were similar for the pre- and post-tests, but the traditional classroom scored higher than the flipped classroom for the 3-month retention test. There were no significant differences between classroom styles for improvement from pre- to post-test for exotropia ( $P = 0.08$ ), but there was greater improvement in the flipped classroom compared with the traditional classroom for esotropia ( $P = 0.01$ ). *ET*, esotropia; *XT*, exotropia.

Anonymous Likert-style survey results for resident satisfaction with preparation and in-class activities, comparing preparation and classroom styles

**Table 1.**

Exotropia					
Satisfaction scores <sup>a</sup>	Level of preparation		P value	95% CI	
	50%	25%			
Preparation activity, mean ± SD	3.42 (0.54)	1.75 (1.59)	<0.001	-2.08, -1.25	
In-class activity, mean ± SD	3.59 (0.74)	3.71 (0.53)	0.47	-0.21, 0.44	
Classroom style					
	Flipped	Traditional			
Preparation activity, mean ± SD <sup>b</sup>	3.53 (0.47)	3.30 (0.59)	0.06	-0.01, 0.47	
In-class activity, mean ± SD <sup>b</sup>	3.56 (0.63)	3.62 (0.85)	0.73	-0.40, 0.28	
Esotropia					
Satisfaction scores <sup>a</sup>	Level of preparation		P value	95% CI	
	50%	25%			
Preparation activity, mean ± SD	3.44 (0.64)	1.30 (1.57)	<0.001	-2.57, -1.71	
In-class activity, mean ± SD	3.55 (0.67)	3.30 (0.94)	0.13	-0.58, 0.08	
Classroom style					
	Flipped	Traditional			
Preparation activity, mean ± SD <sup>b</sup>	3.46 (0.73)	3.40 (0.47)	0.68	-0.24, 0.36	
In-class activity, mean ± SD <sup>b</sup>	3.51 (0.76)	3.62 (0.78)	0.48	-0.42, 0.20	

CI, confidence interval; SD, standard deviation.

<sup>a</sup> Residents were asked about the effectiveness of the coursework based on a Likert scale from 1 to 4, with 1 being least effective and 4 being most effective. Two differently worded questions were posed (Cronbach statistics: 0.99 for preparation and 0.96 for in-class activity) and the average of the two scores were analyzed.

<sup>b</sup> For 50% preparation only.

**Table 2.**

Results (summarized) from online survey on advantages and disadvantages of the flipped classroom format

<b>Flipped-classroom format</b>	<b>No. (%)</b>
Advantages <sup>a</sup> (n = 62 responses)	
More interactive and engaging way to learn	27 (44)
Incentivizes preclass preparation	9 (15)
Improved retention with interactive format	7 (11)
Arrive to class with questions and knowledge foundation	6 (10)
Encourages peer discussions	5 (8)
Critical thinking and problem-solving skills	4 (6)
Disadvantages (n = 60 responses)	
Limited utility without adequate preparation	13 (22)
Requires more upfront work and time	13 (22)
Quality depends on group dynamic and knowledge base	10 (17)
May not cover as much information	9 (15)

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