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The FLIPPED STEP study: A randomized controlled trial of flipped vs. traditional classroom teaching in a university-level statistics and epidemiology course

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ABSTRACT

A flipped classroom, also known as flipped learning, is a teaching method in which students watch online lectures at home, followed by group work in the classroom. This study aimed to evaluate the efficacy of a flipped classroom vs. traditional lectures in a statistics and epidemiology course at Oslo Metropolitan University. The study used a pragmatic randomized controlled trial design in which one group of students received traditional lectures, while another group received flipped classroom teaching. Each participating student had previous experience with both teaching methods. No difference was found in exam grades between the two groups, but the students preferred the flipped classroom significantly ($p = .008$). Students who received instruction in the flipped classroom preferred this method to a higher degree than those who received traditional lectures ($p = .018$).

1. Introduction

1.1. The flipped classroom

For the past two decades, researchers have examined how different teaching strategies impact learning outcomes and student performance. Teaching methods can be divided into three broad categories: traditional face-to-face lectures, digital teaching, and blended learning. With the onset of the COVID-19 pandemic, many educators were required to adapt their instructional methods to be conducive to digital teaching, and a hybrid of traditional and digital lectures evolved into synchronous digital traditional lectures (i.e., Zoom lectures) (Islam et al., 2020).

In traditional face-to-face lectures, teaching is done in a classroom or auditorium with students physically present; this method has existed the longest, which is why it is called the traditional lecture (Pellas & Kazanidis, 2015; Skodvin, 2016). Digital teaching, or e-learning, is a broad term that is defined as the use of the Internet, computers, or communication technology to acquire knowledge (Hameed, 2016). In digital teaching, digital tools replace the physical classroom setting, rendering learning independent of time and place (Bernard et al., 2014; Potter, 2015; Ryan et al., 2016). An exact definition of blended learning has been a subject of debate among researchers (Bernard et al., 2014), but a combination of face-to-face and digital teaching is central to blended learning (Williams, 2002). However, if only digital or technological elements (like online quizzes or digital blackboards) are included in a traditional teaching method, this is not viewed as blended learning (Bernard et al., 2014; Chigeza, 2014).

In recent years, a teaching strategy known as the flipped classroom, or inverted classroom, has gained traction as educators have sought to find innovative methods to increase student engagement and active participation at school. It is called flipped learning because what is viewed traditionally as homework is moved into the classroom, and the traditional classroom lecture is transferred to the student's home (Gillette et al., 2018). The flipped classroom is a type of blended learning in which initial learning, which traditionally was done through physical lectures in classrooms or auditoriums, is digitalized and can be done from home, independent of time and place (Baepler et al., 2014; Chen et al., 2018; Cheng et al., 2019; Lage et al., 2000; van Alten et al., 2019). The digital components of a flipped classroom often entail short videos of lectures prerecorded by the teacher or a third party, combined with

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auto-correctable assignments. This type of formative self-assessment is viewed as better for student learning than summative assessments (e.g., exams and formal tests) (Andrade, 2019). Initial self-learning is then followed by working together in groups in a classroom, with a teacher acting as a guide (Baepler et al., 2014; Chen et al., 2018; Cheng et al., 2019; Lage et al., 2000; van Alten et al., 2019). In a flipped classroom, assignments that are traditionally completed as homework are collaboratively completed in school by the students and the teacher. A fully digitalized flipped classroom approach is also possible, in which in-school seminars are replaced with synchronous online seminars (Stöhr et al., 2020). In line with technological advances, the flipped classroom has increased in popularity and is becoming more common in educational settings (Bishop & Verleger, 2013).

In recent years, many educators have utilized the flipped classroom approach to increase student engagement, facilitate learning, and address students' diverse learning needs. The pedagogic literature indicates that students learn in different ways and at different speeds. In consideration of these differences, the flipped classroom gives students the opportunity to learn at their own pace before they meet physically with other students and the teacher to work together in groups or through class discussions, further ingraining what has been learned at home. The extant literature has described the advantages of flipped classrooms over traditional classroom teaching (van Alten et al., 2019). Uzunboylu and Karagozlu (2015) claimed that a flipped classroom increases interaction and personalized contact between the student and teacher, that most students react positively toward this type of teaching, and that a need exists for further research on this teaching format's effects. Researchers have also found that a flipped classroom reduces cognitive load compared with traditional lecture teaching (Clark et al., 2005; Kirschner et al., 2006). In a flipped classroom, students receive in-classroom support as they engage with the learning material, stimulating long-term memory (Kirschner et al., 2006; Roehl et al., 2013). A flipped classroom is also said to increase the appeal of self-regulated learning (Lape et al., 2014). Mayer (2014) cognitive theory of multimedia learning asserts that the human mind learns best with the coordinated use of the two information-processing systems—visual/pictorial and auditory/verbal—that are the central point of the online learning material used in flipped classrooms. While the traditional classroom is viewed as a passive form of learning, the flipped classroom may stimulate active, constructive, and interactive engagement from students (Chi & Wylie, 2014). Another advantage described in the pedagogic literature is that a flipped classroom allows students to receive more direct feedback from teachers and peers as they process lesson material through in-class group work, which stimulates learning (Abeysekera & Dawson, 2015; Bergmann & Sams, 2012; DeLozier & Rhodes, 2017; Van den Bergh et al., 2014). A flipped classroom is also believed to increase student satisfaction and motivation (Abeysekera & Dawson, 2015; Seery, 2015).

1.2. Studies comparing flipped classrooms to traditional classrooms

Several studies have evaluated the flipped classroom's effect on student learning compared with traditional lectures, but very few have done so with a full randomized controlled trial (RCT) design. Six meta-analyses published over the past five years have evaluated the flipped classroom's effect and compared it with traditional classroom teaching, but very few of the included studies used an RCT design. Some of these meta-analyses demonstrated the positive effects that flipped classrooms had on learning outcomes (Chen et al., 2018; Cheng et al., 2019; Lo et al., 2017; van Alten et al., 2019), while others did not demonstrate any significant effect (Gillette et al., 2018; Liu et al., 2018). One meta-analysis used student satisfaction as an outcome, but no statistically significant difference was found between the two teaching methods (van Alten et al., 2019). Altogether, nine RCTs were identified in a thorough literature review, of which only four were conducted over the duration of an entire course or an entire semester. Two of these full-course studies demonstrated significantly better exam results with a flipped classroom (Anderson et al., 2017; Foldnes, 2016), and two did not indicate any significant difference between the two teaching methods (Gagnon et al., 2013; Harrington et al., 2015). The other five RCTs had limited designs and time frames. None of these studies detected any significant difference between the exam results of students in flipped and traditional classrooms (Casselman et al., 2020; Heitz et al., 2015; Isherwood et al., 2020; Setren et al., 2021; Wozny et al., 2018).

1.3. Change theory

Change that happens during teaching entails an increase in students' skills, knowledge, and/or attitudes due to teachers, peers, books, digital courses, and/or other teaching materials. Change theory explains change by describing the processes needed for change to occur (Taplin & Clark, 2012). A logic model that illustrates change and the processes connected to it can provide a better understanding of the relationship between the inputs and the impact of the change (Berra, 2018; Kellogg Foundation, 2004). Such a model can help to identify possible disruption points and be used to prevent or fix possible threats to the change. In this study, the change tied to the switch from a traditional teaching method to a flipped classroom was evaluated. A logic model to illustrate this change is shown in Fig. 1.

1.4. The present study's aims

As stated in Section 1.2, many studies have been conducted to investigate the differences in effect on exam scores with traditional lecture vs. flipped classroom teaching. However, only four of these studies followed a pragmatic RCT design over a full semester course with individual randomization of students. The present study aimed to compare the impacts of two teaching strategies, flipped classroom and traditional lectures, on exam grades in a full-semester statistics and epidemiology course at Oslo Metropolitan University's Pharmacy School. A secondary aim was to compare student satisfaction and teaching method preferences in the two teaching groups.

2. Materials and methods

2.1. Experimental design

This study followed a pragmatic RCT design in which real-world evidence was obtained, as the study was conducted within a heterogeneous real-world population and not in an artificial study environment (Gamerman et al., 2019). A TIDieR checklist (Template for Intervention Description and Replication) (Hoffmann et al., 2014), shown in Table 1, describes the study's approach. The following sections describe the materials and methods used in more detail.

2.2. The intervention

The intervention entailed two different teaching methods in a statistics and epidemiology (STEP) course at Oslo Metropolitan University's pharmacy studies program. The two study arms were A) traditional physical lectures at the university and B) a flipped classroom with access to a digital course combined with physical group-work seminars at the university. Each study arm received equal amounts of teacher resources. Group A received 18 one-hour lectures with three hours of preparation before each lecture, totaling 72 hours of teacher time. Group B received 9 four-hour seminars with four hours of preparation before each seminar, also totaling 72 hours of teacher time. The hours of teacher preparation before lectures and seminars were based on Oslo Metropolitan University regulations. The hours spent developing the homework assignments for Group A and the digital course for Group B were not included in these calculations because these resources

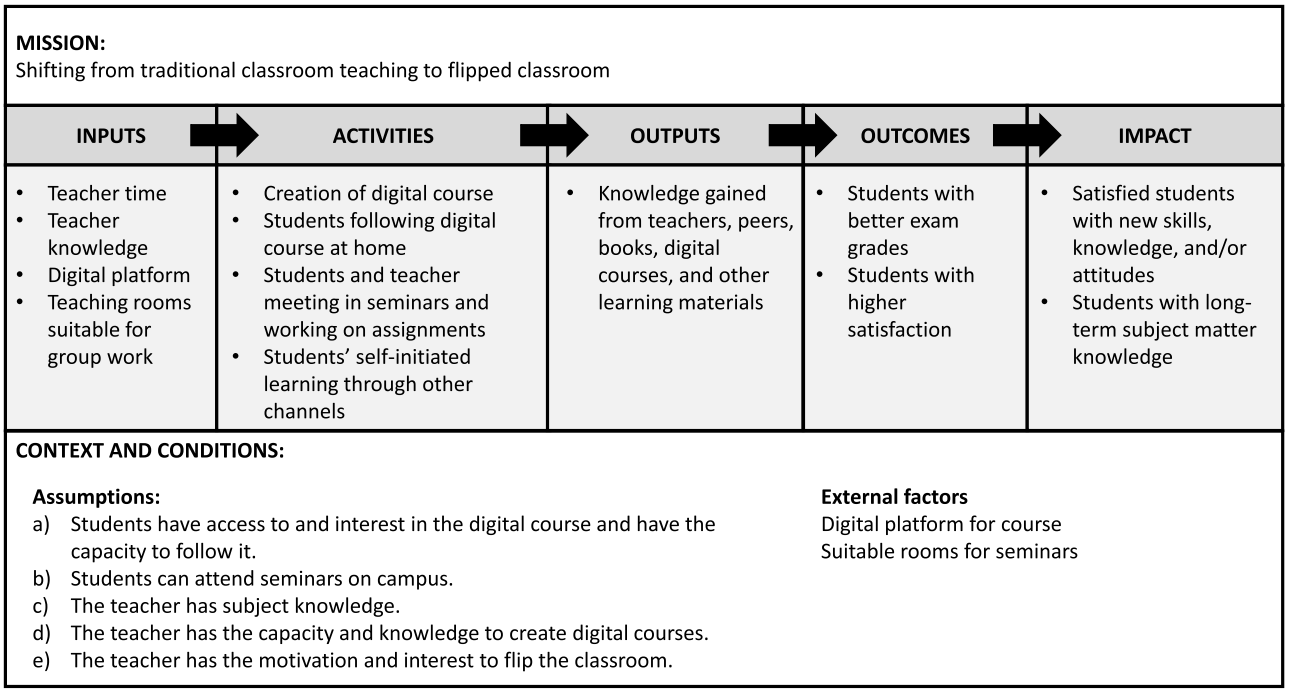

Fig. 1. A logic model of the change from a traditional to a flipped classroom.

already existed. The total number of hours that students were expected to devote to their courses was also equal for the two groups. For Group A, this was 18 hours of lectures and three hours of preparation before each lecture. Furthermore, each student in Group A was expected to spend a total of 43 hours on homework. The students were encouraged to do the homework in independently organized groups. Therefore, the total expected time spent on the course was 115 hours. For Group B, the students were expected to spend four hours in each of the nine seminars and 79 hours going through the digital course. This also totaled 115 hours of expected student time spent on the course, which is in line with the amount of time the university expects students to spend on a course of this length and difficulty.

2.3. Outcomes

The primary outcome was the students' grades on the final exam. In Norway, grades are given on a scale of A–F, with A as the highest grade and F as the failing grade. Grades A–F comprise a categorical ordinal variable that was transformed into a numerical ordinal variable using the following values: A=1; B=2; C=3; D=4; E=5; and F=6. The secondary outcome was the students' satisfaction with their respective teaching method, and the third outcome was the students' preferred teaching method based on previous experiences with both traditional lectures and the flipped classroom in other previously taken courses. The students' satisfaction with teaching and their preferred teaching method were measured with a questionnaire about satisfaction with physical or digital teaching and the assignments in the course. The response alternatives were provided on a five-point Likert scale. The questionnaire was distributed after all teaching was finished but before the final exam. The exam grade data were analyzed with a two-sample t-test, while the questionnaire data were analyzed using non-parametric tests (Mann–Whitney U tests and a Wilcoxon test) due to data non-normality. Furthermore, a general evaluation questionnaire for the course was also distributed to the students, where attendance at seminars and lectures, and the students' degree of digital preparation before the seminars was recorded.

2.4. Randomization and blinding

After giving their consent to participate in the study, the students were individually assigned to either the traditional classroom group or the flipped classroom group through computer-generated random allocation. Students who did not consent to participate in the study received traditional lectures with Group A and were not included in the analyses.

The students obviously could not be blinded to the intervention, but both the internal and external examiners were blinded when grading the exams of both groups.

2.5. Sample and data analysis

The minimum detectable effect size was viewed as one grade before the study. In a similar course from the previous year, the mean exam grade was 2.29, and the standard deviation was 1.15. This was used for power calculations with an alpha of 0.05, a beta of 0.2, and a power of 0.8. This produced a sample size of 21 for each of the two groups. The class comprised 50 students, which was sufficient to conduct the study.

The analyses were performed according to the intention-to-treat (ITT) principle, which implied that all students' outcomes were analyzed according to their randomization group regardless of possible dropouts or subsequent switches between study arms.

2.6. Ethical considerations

The study was approved by the Norwegian Center for Research Data (NSD, Reference No. 204940). The participating students signed consent forms after they were provided with the necessary written information about the trial. The students were informed that they could withdraw from the study at any time and then receive instruction in the traditional classroom group. The data on exam grades were encrypted, and the encryption codes were stored separately from the other data. The questionnaire data were anonymized. The study participants were not viewed as belonging to a vulnerable group, and no harm was associated with the intervention.

Before the project's initiation, the study protocol was approved and published in the American Economic Association's registry for

Table 1
A TIDieR checklist to provide an overview of the study.

Brief name	
1	**Title:** The FLIPPED STEP study – Evaluation of flipped vs. traditional classroom teaching
Why	
2	**Rationale:** This goal of this study was to evaluate whether the flipped classroom had a positive effect on exam grades and student satisfaction compared with traditional classroom teaching in a statistics and epidemiology course.
What	
3	**Materials:** The digital course of the intervention is available upon request at https://bokskapet.oslomet.no/. Other materials used in the intervention and control groups included seminar notes and assignments, lecture notes, and homework assignments. These are available upon request from the first author.
4	**Procedures:**A) Traditional classroom (control group)Traditional lectures presented at the universityHomework after each lectureB) Flipped classroom (intervention group) • Digital course at home before each seminar • Seminars in which students work in groups and complete assignments collaboratively, followed by presentations by either students or teachers in plenum
Who provided	
5	**Provider of intervention:** The first author is employed at Oslo Metropolitan University as an associate professor, and she developed the learning materials for the digital course and assignments, as well as the materials for lectures and seminars. She also provided all the teaching for both groups.
How	
6	**Modes of delivery:** For the traditional classroom group, teaching was delivered through traditional face-to-face lectures. For the flipped classroom group, teaching was delivered through a digital course and face-to-face group-work seminars.
Where	
7	**Locations of intervention:** For the traditional classroom group, lectures were presented in auditoriums at the university. For the flipped classroom group, seminars were presented in seminar rooms specifically designed for group work. The students in the flipped classroom group completed the digital course at home.
When and how much	
8	**Number, duration, and time of intervention:** A) Traditional classroom (control group) • 18 traditional lectures at the university (September to December 2020) • Homework after each lecture B) Flipped classroom (intervention group) • Digital course at home before each seminar • Nine seminars, four hours each (October to December 2020)
Tailoring	
9	No personalization, titration, or adaptation of the intervention was made for any individual. The analyses were performed according to the intention-to-treat (ITT) principle.
Modifications	
10	No modifications were made to the intervention during the course of the study.
How well	
11	**Adherence to the intervention:** Self-reported adherence to the intervention was assessed with a questionnaire question about student attendance in lectures and seminars during the whole course, as shown in Fig. 4. The median answer was that students participated in physical teaching to a large extent in both groups. No statistically significant difference was found in attendance between the two groups.

randomized controlled trials (RCT ID: AEARCTR-0006440).

3. Results

All 50 students in the course gave their initial consent to participate in the study and were randomly assigned to one of the two groups. Both groups' baseline characteristics can be found in Table 2.

Table 2
Baseline characteristics of the students.

	Traditional lecture	Flipped classroom
n	23	27
n female (%)	19 (82.61%)	23 (85.19%)
Mean grade in all previous A-F-graded exams	3.46	3.45 (p=0.950)

3.1. Exam grade results

A two-sample t-test was conducted on the transformed exam grade scores in the two groups to test for the mean difference. Null hypothesis: True difference in mean exam score between students receiving traditional teaching and students receiving flipped classroom is equal to 0. No statistically significant difference was found in exam grades between the two groups (t = -0.63, df = 46.87, p = .530). The mean grade in the group receiving traditional lectures was 2.26, 95% CI [1.82, 2.70], and in the flipped classroom group, it was 2.46, 95% CI [1.97, 2.95].

3.2. Results on student satisfaction with teaching

The differences in satisfaction between the groups were analyzed using Mann–Whitney U tests. There was not observed any statistically significant difference in self-reported satisfaction of the teaching between students receiving traditional teaching (Mdn = "Strongly agree", n = 22) and students receiving flipped classroom (Mdn = "Strongly agree", n = 25), U = 294.5, z = 0.50, p = .629, effect size r = .07. There was also not observed any statistically significant difference in self-reported satisfaction of the assignments and group work between students receiving traditional teaching (Mdn = "Partly agree", n = 22) and students receiving flipped classroom (Mdn = "Strongly agree", n = 25), U = 343.5, z = 1.58, p = .117, with an effect size r = .23. Lastly, no statistically significant difference in satisfaction with the teaching overall was observed between students receiving traditional teaching (Mdn = "Partly agree", n = 22) and students receiving flipped classroom (Mdn = "Strongly agree", n = 25), U = 312.5, z = 0.88, p = .384, with an effect size r = .13. These results indicated that students in both groups were very satisfied with their respective teaching method, but no statistically significant difference was found between the two groups based on either of the three questions about satisfaction. The distribution of the answers can be observed in Figs. 2a, 2b, and 2c.

3.3. Preferred teaching method results

The preferred teaching method was also measured with a questionnaire in which students were asked to mark their preferences on a scale from 1 to 10: 1 indicated a preference for the traditional classroom and 10 indicated a preference for the flipped classroom. Mann–Whitney U tests were used to test for differences in medians between the two groups for these two questions, as shown in Fig. 3. A statistically significant difference was found between the two groups concerning how much the students preferred the flipped classroom. Students receiving the flipped classroom (Mdn = 8, n = 25) preferred the flipped classroom to a higher extent than students receiving traditional teaching (Mdn = 5, n = 22), U = 165, z = 2.37, p = .018, effect size r = .35. A statistically significant difference was also found between the two groups in which teaching method they thought provided the best learning outcomes. Students receiving flipped classroom (Mdn = 8, n = 25) reported that the flipped classroom gave best learning outcome to a higher extent than students receiving traditional teaching (Mdn = 5, n = 22), U = 177, z = 2.11, p = .036, effect size r = .31.

A Wilcoxon test was used to gauge which teaching method the two groups preferred in combination and which method they believe provided the best learning outcome. This test observed whether the

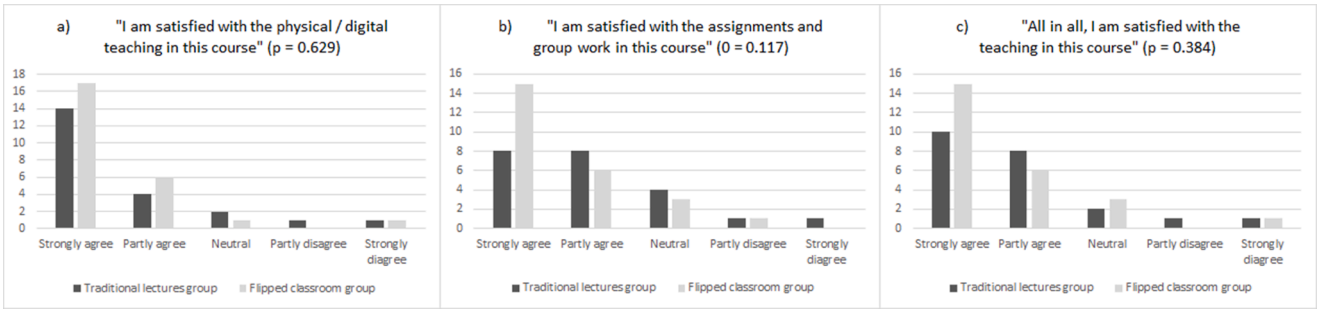

Fig. 2. Degree of satisfaction with the teaching method and assignments.

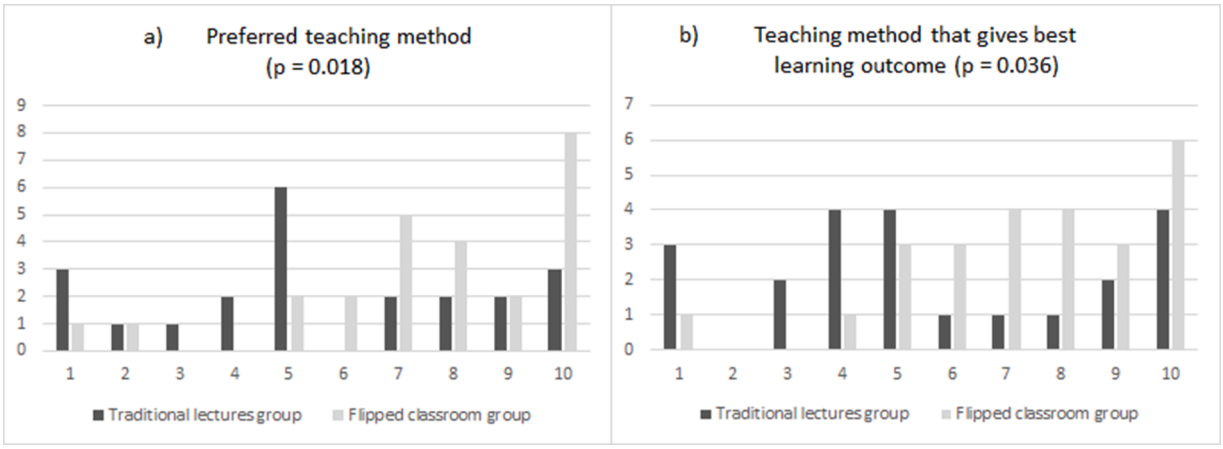

Fig. 3. (a) Preferred teaching method and (b) teaching method that gives the best learning outcome on a scale from 1 to 10, in which 1 indicates a preference for traditional lectures, and 10 indicates a preference for flipped classrooms.

distribution was symmetrical around the middle value on a scale of 1–10. A null hypothesis of no preferred teaching method would provide a symmetrical distribution around the middle value on the scale because the questions were symmetrical regarding the two teaching methods. The results indicated that all students preferred the flipped classroom over the traditional classroom ($Mdn = 7$, $n = 47$), $V = 812$, $z = 2.64$, $p = .008$, effect size $r = .39$, and they reported that the flipped classroom gave them better learning outcomes than traditional lectures ($Mdn = 7$, $n = 47$), $V = 791.5$, $z = 2.42$, $p = .016$, effect size $r = .35$

3.4. Attendance

A Mann–Whitney U test showed no statistically significant difference in students' attendance of physical seminars for the flipped classroom group (Mdn = "Attendance to a moderate extent", $n = 25$) and attendance of physical lectures for the traditional lectures group (Mdn = "Attendance to a large extent", $n = 22$), $U = 219$, $z = 1.33$, $p = .188$, effect size $r = .19$. The distribution of the answers can be observed in Fig. 4.

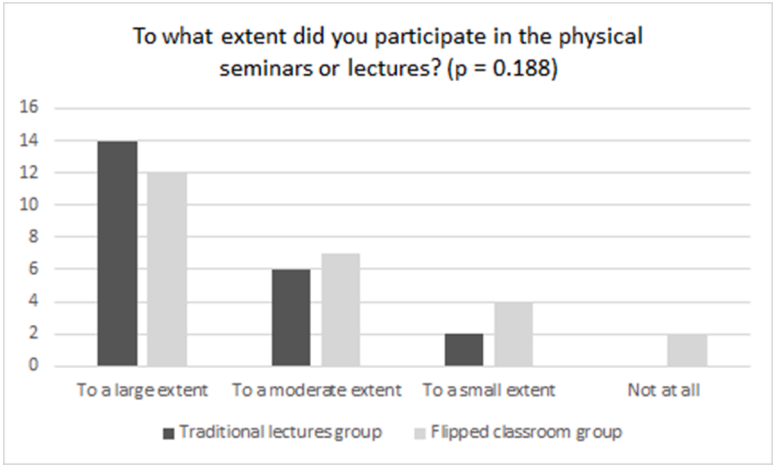

Fig. 4. Attendance of physical seminars and lectures.

4. Discussion

4.1. Pragmatic RCT design

With a pragmatic RCT design, in which students are randomized individually to receive one of two possible teaching methods, a risk of diffusion between the groups always exists. In this course, each student was provided with a personal education login ID to ensure that only the students in the flipped classroom group had access to the digital course. Participation in the traditional lectures and in the flipped classroom seminars was registered to ensure that students did not participate in the physical instruction of the opposite group. Furthermore, a control question was included in the questionnaire, in which students were asked to what extent they participated in the teaching for the other group. Four students reported that they participated in the opposite group, and three of these respondents were from the traditional lecture group. None of these three students were registered to participate in the physical teaching of the flipped classroom group, so these three students most likely collaborated with students in the flipped classroom group using the digital course material. Altogether, 43 out of 47 students who answered the questionnaire (91%) reported that they did not participate in the other group's learning activities.

One student in the flipped classroom group did not follow the intervention and instead followed the traditional lectures. According to the ITT principle, this student's results were included in the intervention group outcomes. One student was unable to take the exam, and three did not answer the questionnaire, resulting in a response rate of 94%. The two groups were very similar regarding mean exam grades in all previous A–F graded courses, ensuring that the use of exam grades as a primary outcome was acceptable.

One teacher, this publication's first author, conducted all the teaching in both groups. This teacher developed the course assignments, which were of equal quality and content for the two groups. The flipped classroom group had self-correcting assignments in the digital course and assignments that were completed during the seminars. The students in the traditional classroom group received the same assignments with suggestions for solutions in a digital pamphlet and were encouraged to form informal study groups and work on these assignments between lectures. This ensured that the students in both groups received instruction and teaching materials of equal quality.

The questionnaire was distributed after the last day of teaching, and students were encouraged to submit their responses before the exam. In this way, the exam grade should not influence the students' perceptions of course quality. The examiners grading the exam were blinded to the treatment groups.

4.2. Does teaching method influence exam grades?

No statistically significant difference was detected in exam grades between students who received the flipped classroom method and students who received traditional lectures, which is one of the outcomes in the logic model of the change in Fig. 1 and is in line with most of the literature. Of the nine RCTs identified in the literature, only two studies demonstrated a statistically significant difference in long-term effects and exam results between flipped and traditional classrooms (Anderson et al., 2017; Foldnes, 2016). Of the six meta-analyses, four concluded that flipped classrooms elicited a greater positive effect on learning outcomes than traditional classrooms did (Chen et al., 2018; Cheng et al., 2019; Lo et al., 2017; van Alten et al., 2019). However, in one of these four meta-analyses, a sub-analysis indicated that this effect was not sustained for RCT-only studies (Chen et al., 2018); one did not include any RCT studies (Lo et al., 2017); one included only one RCT that did not demonstrate a difference in effect (Cheng et al., 2019; Harrington et al., 2015); and one did not conduct an RCT-only sub-analysis (van Alten et al., 2019). Thus, when examining the RCTs only from these meta-analyses, the evidence that flipped classrooms led to better learning outcomes than traditional lectures was not strong. This was similar to the results from seven of the nine identified RCTs (Casselman et al., 2020; Gagnon et al., 2013; Harrington et al., 2015; Heitz et al., 2015; Isherwood et al., 2020; Setren et al., 2021; Wozny et al., 2018). However, some of these RCT studies have certain limitations compared to the RCT of the present study. The Casselman et al. (2020) study used a limited time frame, with only one flipped 1.5-hour lecture. The same applies for Isherwood et al. (2020) with only one flipped 60-minute lecture; Heitz et al. (2015) with only two flipped topics; and Setren et al. (2021) with only a three-lesson unit used for the experiment. Wozny et al.'s (2018) study design was complicated, in which five of the 25 lessons included in the course were flipped in each of seven sections of students. This study found no significant difference in scores between the flipped classroom and traditional lectures on the final exam, which is similar to the results of the present study. Although it was accounted for in the regression model, the possible spillover effect in Wozny et al.'s (2018) study due to switching back and forth between flipped and traditional classrooms did not exist in the present study.

Like most of the RCTs described above, the RCT in the present study did not demonstrate a significant correlation between teaching method and exam grade, although a correlation might still exist. Although the assumed effect size of one grade in the sample size calculations was reasonable, the fact that the null hypothesis could not be rejected does not prove that the effect is necessarily small or nonexistent. In fact, the 95% confidence intervals for the exam grades in the two groups were 1.82–2.70 and 1.97–2.95, demonstrating that the present study does not rule out a substantial effect.

Pedagogic literature expects flipped classrooms to have certain benefits that traditional classroom teaching lacks. Researchers have also described how flipped classrooms reduce cognitive load compared with traditional lecture teaching (Clark et al., 2005; Kirschner et al., 2006). However, this argument is relevant only during lectures, which are only a small part of the learning process for students. Cognitive load could also be an issue during classroom activities in flipped classrooms, depending on how the teacher plans the lessons. In the present study's traditional lecture arm, the teacher divided the lectures into smaller parts and generated active participation from the students to reduce their cognitive load during the lectures. Another argument for why some perceive the flipped classroom to produce greater learning effects is the positive effect of the increased appeal of self-regulated learning (Lape et al., 2014). However, this may not be applicable for students who lack self-regulated learning capabilities (Lai & Hwang, 2016). This was not observed in the present study, in which the students in the flipped classroom group reported completing the digital course material before the classroom part to a similar extent as the traditional lecture group reported attending the physical lectures. Another argument for why the flipped classroom is viewed as eliciting better learning outcomes in the pedagogic literature is because it stimulates active, constructive, and interactive engagement from students (Chi & Wylie, 2014), while the traditional classroom is a more passive learning environment. However, it is not that simple. Traditional classroom teaching can also be active, constructive, and interactive during lectures and homework, which many students complete collaboratively with fellow students. In the present study, traditional lectures were mostly one-way communication lectures, but the students actively asked questions and the teacher held small peer-to-peer discussions between students during lectures. The assignments they were given as homework, which were the same assignments that the flipped group received either during the digital course or in the classroom, were done in self-constructed groups. If the students in the traditional teaching group had questions about the assignments, they would send them to the teacher, who would then discuss the questions at the beginning of the next lecture. Another advantage that the pedagogic literature attributes to the flipped classroom is that students' improved satisfaction with this teaching format increases learning outcomes (Abeysekera & Dawson, 2015; Ryan et al., 2016; Seery, 2015). However, this theoretical effect was not observed in the

present study.

4.3. Student satisfaction, preferences, and learning outcomes

Students in both groups reported high levels of satisfaction with the teaching methods, but no significant difference in satisfaction was found between the two groups. This was the second outcome in the logic model of change shown in Fig. 1. The results of student satisfaction with teaching methods in the literature are diverse. The van Alten (2019) meta-analysis also reported no statistically significant difference in student satisfaction between the two teaching methods. Among the RCTs previously presented here, Gagnon et al. (2013) reported no significant difference between groups regarding course satisfaction, while Isherwood et al. (2020) reported improved levels of satisfaction with flipped classroom teaching. The other meta-analyses and RCTs did not include student satisfaction in their analyses. Other non-RCT design studies have reported diverse results. One study reported less satisfaction with flipped classrooms (Missildine et al., 2013), another demonstrated improved satisfaction with flipped classrooms (Street et al., 2015), and one did not demonstrate a difference in satisfaction between students in a flipped classroom and those receiving traditional lectures (Whillier & Lystad, 2015).

Even though no significant difference in satisfaction with the two teaching methods was found, a significant difference was observed in the question about preferred teaching method. Both groups significantly preferred the flipped classroom over traditional lectures and thought that the flipped classroom method gave them better learning outcomes. This demonstrates that assumptions a and b in the logic model of change were fulfilled (i.e., students need to have access to the digital course, an opportunity to attend seminars, as well as an interest in and the capacity to follow the course). Even though both groups preferred the flipped classroom, the flipped classroom group preferred the flipped classroom to a significantly higher degree than the traditional lecture group. This was the case though all the students had previously received both flipped classroom and traditional lectures in other courses with other teachers or with the same teacher in this course. This demonstrates that experiences with the teaching method received most recently were more likely to influence students' general perceptions of their preferred teaching method. In the literature, students' perceptions of the flipped classroom are somewhat mixed but generally positive (Bishop & Verleger, 2013; Lo et al., 2017; Palmer, 2015), with some students preferring to watch videos instead of read textbooks (Alpaslan et al., 2015) or preferring the flipped classroom because traditional homework is converted into an in-class activity (Talbert, 2014). However, some studies have demonstrated greater satisfaction with traditional lectures compared to flipped classrooms (Cilli-Turner, 2015).

4.4. The flipping-the-classroom discussion's future

In the logic model of the change in Fig. 1, assumptions c, d, and e concern the teacher (i.e., the teacher's subject knowledge, capacity, and knowledge in creating digital courses, motivation, and interest in flipping the classroom). The teacher in this study had several years of experience in both flipped and traditional lecture formats within statistics and epidemiology, as well as in other subjects at the university. Previous student evaluations indicated that students were very satisfied with her teaching in both flipped and traditional classes. For this study, it was important that the same teacher instruct both groups during the physical classroom parts, design the digital course, and produce most of the learning materials and videos for the digital course. The students in both groups were very satisfied with the teaching, with no statistically significant difference found in either the satisfaction with teaching method or the exam grades of the two groups. This led us to question whether teaching quality exerts more influence on student learning than the teaching method itself (i.e., flipped classroom vs. traditional lectures). Another question was how much of the exam grade effect could be attributed to formal teaching and how much was attributed to students' self-initiated learning through channels other than those provided by the university, which was one of the points in the activities part of the logic model. Further research on this aspect is encouraged. The third perspective on the flipping-the-classroom discussion concerned student preferences. Even though the students in both groups reported high satisfaction with the teaching, they significantly preferred the flipped classroom over traditional lectures in this study. One implication of this might be that if a student must take a course that is taught with a method that they do not prefer, this may affect learning outcomes and their overall satisfaction with the course. The fourth perspective concerned the teacher's preferences for teaching methods, which may influence teaching quality. This was mentioned in assumption e of the logic model. The fifth perspective of the discussion concerned the resources available for both teaching and developing course material. Teacher time and knowledge, teaching rooms, and available digital platforms were necessary inputs in the logic model. The overhead costs related to physical teaching were minimal but slightly higher for the flipped classroom method because the seminars in this study had a longer duration than lectures. The open-source platform Open edX was used for the digital course in this study, but costs related to the support and storage of the course content should also be considered. Developing flipped classroom materials is more time consuming and resource demanding than planning traditional lectures (Gillette et al., 2018; McLaughlin et al., 2014). Flipped classroom teaching seems to require more resources when designing and producing, but once the digital components are developed, flipped classrooms require fewer resources to conduct and reuse than traditional lectures (McLaughlin et al., 2014). The long-term benefits of the flipped classroom should therefore be considered when choosing teaching methods.

We recommend the increased use of flipped classrooms in general, as long as the required resources are available and do not clash with teachers' or students' preferences.

4.5. Conclusion

Even though this study did not demonstrate that one teaching method is better than the other with respect to objective learning outcomes, the fact that the students preferred the flipped classroom overall and reported that they learned more from this teaching method is a valid argument for recommending this method in the future.

Availability of data and material (data transparency)

Data are available on request

Authors' contributions

Although the first author has done the major part of this research, both co-authors have also contributed significantly to this paper and therefore qualify as authors. All three authors have 1) made substantial contributions to the conception of the work, the data acquisition, analysis and interpretation of data; 2) drafted the work and revised it critically; 3) approved the version to be submitted; and 3) agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Ethics approval

The study has been approved by NSD – Norwegian centre for research data, and informed consent has been collected from all students participating in the study. Data has been stored according to the regulations provided by the NSD approval.

Study protocol

The study protocol has prior to initiation been approved and published in the American Economic Association's registry for randomized controlled trials. RCT ID: AEARCTR-0006440.

Declaration of Competing Interest

The authors have no financial or non-financial interests to disclose.

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Supplementary materials

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