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The impact of class attendance on student learning in a flipped classroom

Njål Foldnes
Associate professor, BI Norwegian Business School
njal.foldnes@bi.no

ABSTRACT

We investigate the relationship between class attendance and academic achievement in a flipped classroom that was designed to foster social learning in fixed groups. Controlling for initial mathematical skill and attitudes, we found a substantial effect of class attendance on student achievement. Increasing class attendance by one standard deviation was associated with an increase in mathematics performance of 0.28 standard deviations. Neither attitudes nor initial mathematical skill predicted class attendance. We conclude that availability of online videos does not eliminate the need for carefully designed in-class sessions in order to maximise student learning. Communicating this finding may help reduce absenteeism in the flipped classroom.

Keywords
Flipped classroom, Class attendance, Attitudes toward mathematics

INTRODUCTION

Among higher education instructors it is common to strongly encourage students to attend to their classes, so that students can learn more and gain better grades. Still, many classes experience a high degree of absenteeism. The connection between class attendance on student learning has received considerable attention, and a clear and positive relationship between class attendance and course grades has been established. In a meta-analysis based on 69 classes Credé, Roch, and Kieszczynka (2010) conclude that class attendance is the most accurate known predictor of academic achievement. In a recent synthesis of meta-analyses, parallelling the work of Hattie (2008) in school education, Schneider and Preckel (2017) rank 105 variables that are related to achievement in higher education, and rate class attendance number six among these. The many individual studies underlying the syntheses of Credé et al. (2010) and Schneider and Preckel (2017) were conducted mostly in lecture-based classes. In the present article, we investigate class attendance in a flipped classroom, and how it relates to test performance and student attitudes. To the best of our knowledge, the present study is the first to investigate attendance effects in the context of a flipped classroom.

The flipped classroom implements a blended learning environment, and is characterised by moving information-transmission teaching out of class, filling in-class sessions with active and social learning and requiring students to complete pre- and/or post-class activities to benefit from in-class work (Abeysekera & Dawson, 2015). Course content is delivered in online video lectures, which are typically watched and contemplated by students as preparation for in-class work, where students interact with their peers and with the instructor. The literature concerning the effectiveness of the flipped classroom is diverse and rapidly growing; for literature reviews and surveys, see Bishop and Verleger (2013); O'Flaherty and Phillips (2015); Zainuddin and Halili (2016); DeLozier and Rhodes (2016). No conclusive evidence have yet emerged on whether student achievement improves with flipped instruction, due to the wide array of subject matter across studies, often with only partial adoption of flipped instruction in some modules of the course, the lack of statistical control, and the many different flipped classroom formats. However, in the reviews of O'Flaherty and Phillips (2015) and Zainuddin and Halili (2016) it is argued that some evidence exists for improved academic performance with the flipped approach. In addition, some recent findings point in the same direction,e.g, Balaban, Gilleskie, and Tran (2016) found positive effects of the flipped classroom in a principles of economics course, while in a randomised experiment conducted in an introductory mathematics course for business students, Foldnes (2016) reported increased student performance in the flipped classroom compared to the lecture-based classroom.

Pedagogically, the flipped classroom framework is inspired by the possibility to create social learning opportunities in the space freed up by outsourcing basic knowledge transmission to online videos. The socio-constructivist view of learning argues that knowledge is socially constructed through interaction, engagement and participation. That is, learning is created through continuous transactions between the student and the environment. Hence the student learns best by being engaged in interaction with peers, context and content. Of special relevance here is Vygotsky's well-known zone of proximal development (Vygotsky, 1980), where students interact with more capable peers and internalise their actions as their own. Consequently, in the present study, the flipped classroom implementation was designed to encourage peer learning in fixed groups.

Although there is growing empirical evidence for improved student learning using the flipped instruction format, and despite its basis in widely accepted theories of active and social learning, students may still choose to be absent from flipped classroom sessions. Indeed, a common worry among instructors contemplating the classroom flip is whether the already low attendance rates in lectures may be further reduced in the flipped classroom, in turn leading to lower student grades. It is argued that students may conceive the in-class sessions as redundant, given the online availability of video course content. Students may argue to themselves that it is the availability of online videos, which can be studied at any time at any rate, that is, with pausing and rewinding, that will help them learn mathematics.

The purpose of the present study was to investigate learning outcomes in a large flipped classroom for first-year undergraduates at a Norwegian business school, and how it is affected by the student's attitudes and class attendance. For the student it is important to know whether substantial learning opportunities are available in the flipped class sessions. For the instructor it is important to know whether the work needed to redesign in-class sessions for on active and social learning will lead to increased student learning. The article is organised as follows. In the following two sections we discuss methods and present results. In the fourth section we discuss our findings and limitations, while the final section contains concluding remarks.

METHODS

An introductory mathematics course for first-year students at a Norwegian business school was used for this study. The course covered mainly pre-calculus topics, and was taught during the fall semester 2015, over twelve weeks. The first week an introductory lecture was given in an auditorium, containg a course overview, introduction to the flipped classroom mode of learning, and information on which group each student was assigned to. The next ten weeks contained three-hour flipped classroom sessions, covering the whole course content. The physical learning environment for the flipped classroom consisted of an open study area with tables, and with adjoining study cells where groups could assemble and work on a whiteboard. Each week students were told to watch online videos as preparation for the next in-class session. The videos were screencasts produced by the instructor and posted on Youtube. Typically the material covered in 45 minutes in a traditional lecture was condensed into a compact video lasting 10–15 minutes. Students were asked to watch two or three videos at home each week. The in-class flipped classroom sessions were organised as follows. First, students were given a sheet of paper with twenty exercises and were asked to try to solve these individually for 60 minutes. One third of the exercises was repetition material on topics covered in earlier weeks. The other two thirds pertained to the new material that students had watched as preparation for the session. The rest of the session was organised to foster collaborative learning experiences in fixed groups, inspired by the team-based learning framework (Michaelsen, Knight, & Fink, 2002). The aim of the teamwork (consisting of 5–8 students) was to discuss the exercises, compare answers and solution strategies, and after discussion with peers to arrive at common answers in each group. The group scores were collected for an informal contest among groups, but the scores were not used for formal assessment. The instructor and two teaching assistants were present to guide and help students both individually and in groups. The last of the twelve sessions was given by the instructor in the auditorium, and contained a course round-up.

Participants

Participants in this study consisted of 241 first-year undergraduate students enrolled in a bachelor of business administration program at a norwegian business school. Mean age was 21 years, with a standard deviation of 3 years.

Measures

Students' attitudes impact on their engagement, participation and performance in mathematics, as was noted already by Neale (1969), who defined attitude toward mathematics as "a liking or disliking of mathematics, a tendency to engage in or avoid mathematical activity, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless". In their synthesis of 105 variables affecting student achievement, Schneider and Preckel (2017) rank student motivation in the form of self-efficacy as the second most important variable. Given this importance, we included measures of attitudes. We adopted a psychometric perspective, where attitudes constitute latent variables that can only be measured indirectly, each through a set of items. In the present study, we translated items into Norwegian from the shortened version of the Attitudes Toward Mathematics Inventory (ATMI) proposed by Lim and Chapman (2013). Three attitude constructs were measured: enjoyment to do mathematics (ENJ), self-confidence in mathematics (SC), and perceived value of mathematics (VAL). ENJ measures the degree to which students enjoy working with mathematics. ENJ was found by Lim and Chapman (2013) to correlate highly with a fourth subscale, namely motivation, which measured interest in mathematics and desire to pursue further studies in mathematics. SC measures the students' confidence and self-concept of their performance in mathematics, and is closely related to self-efficacy. Finally, VAL measures students' belief on the usefulness and relevance of mathematics. All items were scored with a five-point Likert Scale, with options ranging from "strongly disagree" to "strongly agree", and are given in Table 1. We also present mean values and standard deviation for each item. In total, 241 participants completed the shortened ATMI.

Table 1 Mean and standard deviation (SD), items for shortened subscales ENJ, SC and VAL based on the Attitudes Toward Mathematics Inventory.

Label	Full item statement	Mean	SD
ENJ1	I have usually enjoyed studying mathematics in school.	3.4	1.1
ENJ2	I like to solve new problems in mathematics.	3.5	1.0
ENJ3	I really like mathematics.	3.3	1.0
ENJ4	I am happier in a mathematics class than in any other class.	3.6	1.1
ENJ5	Mathematics is a very interesting subject.	3.7	1.0
SC1	Studying mathematics makes me feel nervous.	3.7	1.0
SC2	I am always under a terrible strain in a mathematics class.	3.1	1.2
SC3	It makes me nervous to even think about having to do a mathematics problem.	4.1	1.0
SC4	I am always confused in my mathematics class.	2.6	1.0
SC5	I feel a sense of insecurity when attempting mathematics.	2.9	1.1
VAL1	Mathematics is a very worthwhile and necessary subject.	4.5	0.6
VAL2	Mathematics is important in everyday life.	4.0	1.2
VAL3	Mathematics is one of the most important subjects for people to study.	3.6	1.0
VAL4	Mathematics lessons would be very helpful no matter what I decide to study.	4.2	0.9
VAL5	A strong mathematics background could help me in my professional life.	4.4	0.7

In each of the ten flipped classroom sessions we recorded attendance for each student. Class attendance was then scored on a scale 0–10, indicating the number of sessions attended.

Students have studied mathematics in school for many years, leading to large variability in initial skills when attending college. Such skills may be associated with both attendance rate and mathematics achievement on the post-test, and is therefore necessary to include a measure of initial mathematical skills to control for any confounding effects. The pre-test for mathematical skills contained 16 items in a multiple-choice format, assessing the students' basic skills in secondary education mathematics, and was taken by 241 students.

The multiple choice post-test was conducted during the last session of the course. The number of students present at this session was quite low, resulting in only 106 students taking the post-test. It contained 20 items and had the same format, content and level of difficulty of a typical final exam given in this course. The pre- and post-test scores used in the analyses were sum scores, ranging from 0–16 and 0–20, respectively. Hence, test performance on the post-test served as a proxy for student learning. We acknowledge that students' performance on a multiple choice test might not be the most valid measure of student learning. However, practical constraints did not allow for more refined measurements of student learning. Also, since the post-test was similar in format and difficulty level to the final exam, it gives a realistic picture of student performance on the final exam, but without measurement error often caused by test anxiety. A second reason for using the post-test, and not the final exam, as a measure of student performance, is due to the fact that the final exam was administered three weeks after the post-test. In such a long period of time, the effect of class attendance may become confounded with the effort of self-study in preparation for the exam. That is, students performing poorly on the post-test, possibly due to absenteeism, might put in a stronger effort (cramming for the exam) in order to compensate.

ANALYSIS

The adequacy of the proposed measurement instruments for student attitudes was evaluated. This involved calculating reliability and goodness-of-fit for each subscale, based on confirmatory factor analysis. Previous evaluations of the ATMI questionnaire have been based on using a normal-theory based estimator for continuous data, which is sub-optimal, given the ordered-categorical nature of the items. We therefore employed a proper estimation method and goodness-of-fit measure, i.e., the diagonally weighted least squares estimator in conjunction with the polychoric correlation matrix and a scaled-and-shifted chi-square statistic, as implemented in the R package lavaan (Rosseel, 2012).

The main aim in the present study was to investigate the relationship between class attendance and student learning. Based on the discussion by Credé et al. (2010) we proposed three increasingly complex causal models. The models are given a graphical representation in Figure 1.

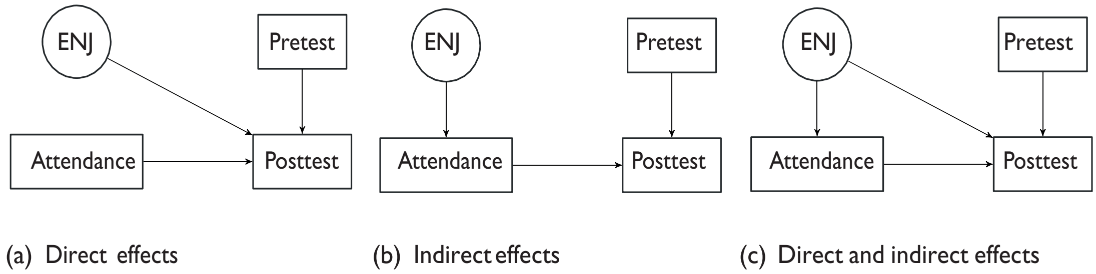


Figure 1. Postulated models for the impact of attitude (ENJ) and attendance on achievement (post-test), while controlling for initial skills (pre-test).

In the figure, for illustrative purposes, we used ENJ. Similar models are obtained by replacing ENJ either by SC or by VAL. The most simple model is a direct effects model, denoted by Model A, where attitudes, preliminary skills and class attendance all predict mathematics achievement directly. In this model attitudes have a direct impact on achievement, without passing through class attendance. That is, highly motivated students may learn a lot without coming to class. This possibility is especially plausible in a flipped classroom compared to the lecture-based classroom, since online videos are constantly available for self-studying. In Model A we can estimate the effect of attendance, while controlling for preliminary skills and attitudes toward mathematics. Next, consider the mediated effects model, denoted by Model B. In this model the effect of attitudes is fully mediated by class attendance. That is, there is no direct effect of attitudes on math achievement. Instead, attitudes may affect class attendance, which again predicts math achievement. The final model, Model C, is a merging of the direct and mediated effects models, allowing for both direct and indirect effects of attitude on math achievement. Note that the students' pre-test score was used as a control in all models, ensuring that individual differences in initial mathematical skill did not confound the relationships of interest.

We finally remark that the models presented in Figure 1 contain only one attitudinal construct (e.g. ENJ). An alternative would be to instead include all three (ENJ, SC and VAL) in a single comprehensive model. However, this would yield a large model with a large number of free parameters to be estimated from a rather modest sample size. For instance, adding only ENJ to the model where SC is already included as a predictor adds 27 more parameters (5 factor loadings, 15 threshold parameters, 1 regression coefficient and 1 covariance) to the model. Also, we expected ENJ, SC and VAL to be highly correlated, which would inflate standard errors and lead to loss of precision in the estimated effects of each attitudinal construct.

RESULTS

Shortened ATMI

In this section we investigate measurement properties of the three attitudinal constructs ENJ, SC and VAL. Model fit, reliability and relation to attendance and posttest score are reported in Table 2.

Table 2

Measure	RMSEA	CFI	SRMR	α	β_{Att}	γ_{Att}	β_{Post}	γ_{Post}
ENJ	0.11	0.99	0.02	0.90	0.01	0.04	0.28***	0.48***
SC	0.08	1.00	0.03	0.82	0.02	0.04	0.25***	0.49***
VAL	0.11	0.98	0.04	0.84	0.11	0.04	−0.14	0.49***

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

RMSEA = root mean square error. CFI = comparative fit index. α = Reliability based on polychoric correlations. β_{Att} = standardised effect of Measure on class attendance. β_{Post} = standardised effect of Measure on post-test. γ_{Att} = standardised effect of pretest on class attendance. γ_{Post} = standardised effect of pre-test on post-test.

Many fit indices exist for evaluating goodness-of-fit in latent variable models, and we report three of these: the root mean square error of approximation (RMSEA), the comparative fit index (CFI) and the standardized root mean residual (SRMR). Hu and Bentler (1999) recommended reporting the CFI together with the SRMR, and suggested a combination rule for acceptable fit as CFI > 0.95 and SRMR < 0.08. Hence, under this rule, it appears that the ENJ, SC and VAL instruments all have reasonably good model fit. This resonates with the findings of Lim and Chapman (2013) and Ngurah and Lynch (2013), who reported satisfactory performance of the subscales in samples from Singapore and South Australia, respectively. However, the RMSEA for all three constructs suggests that the fit is mediocre to poor. However, it is known that RMSEA becomes inflated in small models (Breivik & Olsson, 2001). Reliability, i.e, Cronbach's α, for sum scores associated with ENJ, SC and VAL were estimated based on polychoric correlations, as recommended by Gadermann, Guhn, and Zumbo (2012). The reliabilities are deemed to be within an acceptable range for all three instruments. To sum up, we conclude that the fit and reliability of ENJ, SC and VAL are adequate, and we proceed to use these instruments in further analysis.

DOES ATTITUDE AFFECT ATTENDANCE AND POST-TEST SCORES?

Models B and C in Figure 1 postulate direct effects of attitude on both attendance and post-test scores. This may be tested for, e.g., ENJ, with the following models:

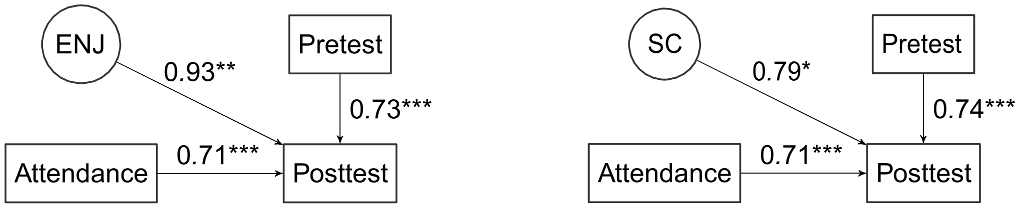
$$Attendance = \tilde{\alpha} + \beta_{Att} ENJ + \gamma_{Att} Pretest + \tilde{\delta} \quad (1)$$
$$Posttest = \alpha + \beta_{Post} ENJ + \gamma_{Post} Pretest + \delta \quad (2)$$

Here, the estimate of e.g. β_{Post}, and its significance, is a measure of the relationship between ENJ and posttest scores, controlling for initial mathematical skills. Note that the first model above was estimated in the full n = 241 sample, while the second model was estimated in the n = 106 subsample. In Table 2 we present the regression coefficients for these two models, and also with ENJ replaced by either SC or VAL in equations (1) and (2). The standardised estimates β_{Att} are not significant for any of the attitude constructs. This means that variation in attitudes toward mathematics is not translated into variation in class attendance. Consequently, models B and C in Figure 1 are not supported by the data. It is also noteworthy that the pretest score does not predict class attendance.

In Table 2 the effects of ENJ and SC on student learning, as estimated by β_{Post}, are significant. This suggest that ENJ and SJ cause behavior or cognitive processes other than attending class, that in turn leads to increased learning, lending support for Model A in Figure 1. As for VAL, it does not predict neither attendance nor post-test scores, and is hence excluded from further discussion.

THE EFFECT OF CLASS ATTENDANCE ON STUDENT LEARNING

We proceed to estimate model A for SC and ENJ, where these constructs have a direct effect on student learning, but no indirect effect as mediated by class attendance.



(a) Controlling for ENJ. (b) Controlling for SC.

Figure 2 . The effect of class attendance on post-test scores. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

The models are depicted in Figure 2, where unstandardised estimates are included. Note that the variance of the latent variables SC and ENJ was constrained to unity, in order to facilitate interpretation of the corresponding regression coefficient. Tables 3 and 4 contain estimates and standard errors for the two models in Figure 2.

Unsurprisingly, since SC and ENJ are strongly correlated ($r = +0.7$) the models in panels a) and b) of Figure 2 contain almost identical estimates. Importantly, the effect of class attendance on posttest scores is highly significant. Class attendance will lead to increased performance on the posttest, even when controlling for initial skills and attitudes toward mathematics. The practical significance amounts to the following. Imagine two students A and B with the same attitudes toward mathematics, and the same initial mathematical skill. If A attended three more flipped classroom sessions than B, we expect A on average to get two more correct answers than B on the posttest. Alternatively, the standardised effect of classroom attendance was estimated to be 0.28 for both the SC and ENJ models. This means that a student who attended class one standard deviation above the mean class attendance is expected to score 0.28 standard deviations above the mean posttest score. Also, initial mathematical skills is a strong predictor for posttest performance.

Table 3 Factor loadings and regression coefficients for ENJ model in left panel of Figure 2.

			estimate	se	z	pvalue
ENJ	=˜	ENJ1	0.80	0.04	19.53	0.00
ENJ	=˜	ENJ2	0.87	0.03	27.12	0.00
ENJ	=˜	ENJ3	0.92	0.03	30.25	0.00
ENJ	=˜	ENJ4	0.78	0.05	14.88	0.00
ENJ	=˜	ENJ5	0.79	0.05	17.04	0.00
Posttest	˜	ENJ	0.93	0.38	2.45	0.01
Posttest	˜	Attendance	0.71	0.25	2.88	0.00
Posttest	˜	Pretest	0.73	0.12	6.19	0.00

Table 4 Factor loadings and regression coefficients for SC model in right panel of Figure 2

			estimate	se	z	pvalue
SC	=˜	SC1	0.73	0.08	9.28	0.00
SC	=˜	SC2	0.37	0.08	4.38	0.00
SC	=˜	SC3	0.91	0.07	13.39	0.00
SC	=˜	SC4	0.54	0.08	6.74	0.00
SC	=˜	SC5	0.82	0.06	13.90	0.00
Posttest	˜	SC	0.79	0.41	1.95	0.05
Posttest	˜	Attendance	0.71	0.25	2.86	0.00
Posttest	˜	Pretest	0.74	0.12	6.20	0.00

DISCUSSION

A large part of the literature on attendance demonstrates that class attendance is positively associated with increased learning. These studies were conducted in lecture-based classes. The main aim in the present paper was to establish whether the same strong link occured in a flipped classroom. The flipped instruction mode makes course material available online in the form of video lectures. To the extent that students are able to learn mathematics from watching online videos, one might speculate that class attendance is less important in a flipped classroom than with lecture-based instruction. On the other hand, in accordance with the socio-constructivist perspective, learning is a socially constructed through interaction, engagement and participation.This means that an important part of learning is based on engagement, activity and participation in interaction with peers, context and content. Such a view suggests that flipped classroom sessions that are structured to encourage group learning will enable students to learn more than they would from merely watching and rewatching tutorial videos. Our findings suggest that this is indeed the case. In fact, the meta-analytical study by Credé et al. (2010) reports a correlation between attendance and academic achievement based on 69 classes of $\rho = 0.44$. In the present study, the observed correlation between attendance rate and post-test score was at the same order, at $\rho = 0.49$. Moreover, the strong relationship between attendance and academic achievement still prevails after controlling for attitudes toward mathematics and mathematical skills at the start of the course.

We next discuss some limitations in the present study. We lacked good explanatory variables for class attendance in the current study. In short, neither initial mathematical skills nor attitudes toward mathematics are related to class attendance. This result echoes the meta-analytical finding of Credé et al. (2010), where student characteristics and class attendance were found to be only weakly correlated. Credé et al. (2010) suggest that other individual difference variables may help understand attendance, such as self-control, delay gratification and long-term orientation. Also, as noted by one reviewer of this paper, our motivation was measured only once, before participation in the flipped classroom. Positive attitudes might increase, especially enjoyment, after participating in class, which then potentially could affect attendance. This hints at a reciprocal and dynamic relationship between behaviour (attendance) and attitudes (enjoyment of mathematics), a topic which might be investigated by assessing attitudes at several time points in future panel studies.

In the present study we did not have available data on the use of videos. Such information would allow us to investigate the contribution of online videos to student learning. It would be interesting to explore whether attitudes toward mathematics, have an effect on learning as mediated by the use of videos for self-study at home. Future work on class attendance effects in the flipped classroom would benefit from including data on the use of videos, which could also yield insight in the direct effect of videos on student learning.

Another limitation is the moderate sample size at the second data collection occasion, due to many absent students at the last session of class.

CONCLUSION

We have demonstrated that, controlling for attitudes toward mathematics and initial performance in mathematics, class attendance in a collaborative-learning oriented flipped classroom has a significant and practical effect on student learning. Specifically, attending one extra flipped classroom 3-hour session resulted in an expected increase on the 20-point posttest score of 0.71 points. This suggests that a flipped classroom containing active and social learning opportunities leads to increased student learning, over and above the learning produced by interacting with the online videos. This is important, given concerns that class attendance in flipped classrooms may be lower than in traditional lectures, possibly due to wrongly held views among students that the videos replace in-class lectures, decreasing the importance of attendance in a flipped classroom, compared to the traditional lecture-based course. In fact, the relationship between attendance and achievement was as strong in the flipped classroom as those reported in most lecture-based classrooms.

The results reported in the current study may be used by instructors to argue to students that class attendance is an effective road to learning also in the flipped classroom. Also, we hope our findings might help inspire instructors to implement blended learning methods like the flipped classroom, with strong focus on structured group learning sessions.

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