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Can the flipped-classroom approach (FCA or pre-learning) improve engagement and progress in maths in year 10 high achiever students?

Introduction and literature review

Flipped classrooms (FC) or flipped learning (or pre-learning) approaches are fast becoming a popular practice in mathematics classrooms, providing opportunities for students to learn anywhere, at any time. A flipped pedagogical approach may go some way in addressing the continuing issue of student disengagement with mathematics, yet how do we know if it really works? Does it promote progress? And what are the advantages and disadvantages to flipped approaches?

First, let's consider how flipped learning works. There are various approaches that range from the provision of direct instruction via the use of video recorded lectures, to those that allow teachers to individualise learning according to student needs. The fundamental reason flipped learning approaches evolved was to take advantage of new technologies that allow for the introduction of new knowledge via multi-media and shift passive learning (via direct instruction) to allow teachers and students to make better use of classroom time. Pre-lesson materials can take the form of prescribed readings, teacher-produced videos, screencasts that may incorporate resources created on software such as GeoGebra, videos sourced from Youtube, or resources created by others such as Khan Academy. Face to face lessons can then be freed up for more teacher/student and student/student interaction, collaboration, application of learning through problem solving and investigation, and opportunities to provide intervention where necessary (Bhagat, Chang, & Chang, 2016; Lo & Hew, 2017; Weinhandl, Lavicza, & Süss-Stepancik, 2018).

Bishop and Verleger (2013) formulate a definition of flipped classroom approach (FCA), as a technology-supported pedagogy that consists of two components: (1) direct computer-based individual instruction outside the classroom through video lectures and (2) interactive group learning activities inside the classroom.

Based on this definition, the review by Lo & Hew, 2017 yielded 15 empirical studies of K-12 (students aged 13 to 18, only two studies had 8-year-old primary school children) FCs related to the STEM field.

To investigate student achievement in K-12 FCs, the authors focused specifically on comparison studies (e.g., quasi-experimental) that involved at least one group of FC and one group of traditional classroom. Five studies reported that the students in FC either performed overall significantly better than the students in traditional classroom (Bhagat et al. 2016; Chao et al. 2015; Schultz et al. 2014; Tsai et al. 2015) or performed better on certain aspect (Huang and Hong 2016). Four studies found no significant difference in student achievement between the FC and traditional classroom (Chen 2016; Clark 2015; DeSantis et al. 2015; Kirvan et al. 2015). In the present review, no study reported a detrimental or inferior effect of FCs on student achievement.

However, the following three limitations in some K-12 studies could have affected their comparison of student achievement: 1) not all studies utilized a pre-test or pre-treatment assessment to evaluate the initial equivalence among groups (see Bhagat et al. 2016; Chao et al. 2015; DeSantis et al. 2015; Huang and Hong 2016; Kirvan et al. 2015 for exceptions), 2) the duration of interventions was short in general, ranging from 4 weeks to 4 months, 3) a majority of the comparison studies in the present review were conducted in the contexts of K-12 mathematics education (e.g., Bhagat et al. 2016; Clark 2015; DeSantis et al. 2015; Kirvan et al. 2015). More empirical studies from other subject disciplines such as English are required to examine the general effects of K-12 FCs on student achievement (Huang and Hong 2016).

Students were generally satisfied with the use of FCA (e.g., Bhagat et al. 2016; Schultz et al. 2014; Snyder et al. 2014; Clark 2015). More specifically, qualitative comments suggested the following three advantages of flipped classroom approach which contributed to a high satisfaction of the flipped courses: 1) students reported that watching the video lectures before class helped them prepare for the class activities (e.g., Chao et al. 2015; Grypp and Luebeck 2015; Huang and Hong 2016; Tsai et al 2015; Wang 2016) and that it was easier than reading text-based materials (Snyder et al. 2014), 2) FCA helped increase interactions with the classmates and teacher during class meetings (Chao et al. 2015; Chen 2016; Clark 2015; Schultz et al. 2014), in-class activities such as group discussion promoted students' interactions with their peers (e.g., Clark 2015; Grypp and Luebeck 2015; Kettle 2013), and the teacher could offer timely assistance in FCs (Tsai et al. 2015), improving their understanding on the topics Clark's (2015), 3) there were greater opportunities for students to apply the new knowledge in solving problems (Chao et al. 2015; Mazur et al. 2015; Schultz et al. 2014) and engage in the discussion of higher level problems (Tsai et al. 2015).

Contrary to these positive findings, DeSantis et al. (2015) discovered that the satisfaction of their FC was significantly lower than that of their traditional classroom. They illustrated that students generally reacted negatively toward the change of instructional approach. Chen (2016) also reported that some students resisted initially because they did not get used to learning at home prior to the lesson. Consequently, some of them skipped the pre-class activities and came unprepared to the class. It thus resulted in a negative impact on the group dynamics of the in-class activities.

The review reveals that there are different challenges in applying the FCA for both students and teachers, e.g., time-consuming pre-class activities to complete and to prepare, students' access to the Internet, teacher's monitoring of students outside class, etc. However, guidelines were formulated by the literature (Bhagat, Chang, & Chang, 2016; Lo & Hew, 2017; Weinhandl, Lavicza, & Süss-Stepancik, 2018), to address these potential challenges.

I chose to implement a FCA intervention in my year 10 top set class because most of the students do not show natural resilience when they face a task that they are not familiar with, even if they are provided with the necessary instructions (through a video, for example), and their engagement is poor. According to most of the literature, the impact of a FCA intervention will help them to become more independent, reflective, resilient and motivated learners, improving their progress in maths.

Methods

Data analyses

This project implements the Flipped Classroom Approach (FCA, Lo and Hew 2017) in a year 10 set 1 class of 27 pupils (band Y) for approximately two months (one full term).

In order to analyse the data, I adopted a mixed-methods approach. Due to ethical reasons (as I am not able to randomly assign pupils in my class to FC and traditional lessons) and to practical constraints (small sample size and the extra-work required from the colleague teaching the other

year 10 set 1 – band X - to participate in the study with their class as control), I followed a quasi-experimental design of the type of pre-test and post-test. The pre-test and post-test design involves administering a pre-test to all participants, followed by intervention, and then comparing the results pre and post-test.

My pre-test quantitative data were given by an average of the results of the two end-of-unit tests done during the first half-term (without the intervention), and the post-test quantitative data were given by an average of the results of the two subsequent end-of-unit tests taken during the intervention period (all end of unit tests are attached).

All end-of-unit tests were assessed by me, hence were not self or peer-assessed by the students. Even though the students were not assessed on the same topic pre and post intervention with the same test (which is a limitation of this study), I was able to see if their average attainment improved or worsened after the intervention, using the scores of the different end of unit tests converted to percentages.

These pre and post averages were compared using a paired t-test. I ran a post-hoc power analysis in G*Power for this two-tailed paired t-test analysis, setting an η^2 effect size of 0.092 (as for the FCA quasi-experiment by Bhagat, Chang, & Chang, 2016), a sample size of 27 and a 5% alpha-significance level.

I also ran two repeated measures Anova within-between interaction analyses (teo-way repeated measures ANOVA) in order to explore if there is any:

1) Effect of behaviour (binary variable drawn from SIMS giving behaviour points at the end of FCA implementation: a pupil having a negative number of point means they have behavioural issues) on scores and on the effect of time on scores.
2) Effect of Pupil Premium (PP) on scores and on the effect of time on scores.

As this analysis has not been done before in the literature, I did a post-hoc power analysis assuming a Cohen's f effect size of 0.25, at a 5% alpha-significance level, with a sample size of 27, with four repeated measures (4 end of unit tests, 2 pre and 2 post), having 0.5 correlation, non-sphericity correction ϵ of 1 and 2 between-factors (time and behaviour, and time and PP).

My pre-test qualitative data were given by the results of a questionnaire on pupils' attitude towards Traditional classroom lessons and the post-test qualitative data were given by the results of the same questionnaire on FC lessons (12 items, 5 open questions; both questionnaires are attached).

The questionnaire is adapted from Barua et al. (2014), which had a test-retest reliability (kappa statistics) of k = 0.94 and its overall Cronbach's alpha was 0.912.

Total scores from the pre-post qualitative data (questionnaire scales 1-5, 1 = strongly disagree, 2 = disagree, 3 = neither agree or disagree, 4 = agree and 5 = strongly agree) were compared using a paired t-test as descripted above. The questionnaire open questions were considered qualitatively: only some of the answers are showed in this report.

Mean and standard deviation were used for descriptive statistics of test scores and questionnaire total scores and percentages were used for descriptive statistics of single item response rate in questionnaire.

To check assumptions for the paired t-test and the two-way repeated measures ANOVA, the Shapiro-Wilk test for normality was run.

Potential risks

There are many challenges in adopting a FCA to guarantee a successful impact and it is important that these are addressed before starting the intervention.

According to the literature (Lo and Hew 2017), to overcome student-related challenges, I did:

- Open up teacher-student communication before flipping: teacher to provide an overview of FCA requirements with an explanation of the steps involved, and students to have a chance to express their concerns about FCA.

- Demonstrate students how to learn through FC: preparing students gradually by making them watch a video during class time and showing them how to take notes.

- Use cognitive theory of multimedia learning to guide video production to avoid assigning long instructional videos (6 minutes is the median engagement time of watching).

- Retain the workload when flipping a course: only give the students out-of-class videos and tasks which will take the same amount of time of traditional homework to avoid students' frustration for extra workload.

- Provide students with communication platform outside the classroom for support: encourage students to use the Outlook school teacher email to ask questions or the Teams class group to promote discussions between peers.

To address faculty challenges, I did:

- Enrich my knowledge of FCA

- Prepare flipped learning material progressively not to accumulate workload.

To address operational challenges, I did:

- Support the students who are limited by technology resources by extending the use of computer facilities in school to support the implementation of FCA or give them additional copies of the FC material on flash drives if students don't have internet connection at home.

- Monitor and motivate students' learning by checking and ensuring that the students have truly watched the video, by giving achievement points and rewards if they do. I will be able to actively monitor students watching the video using one of the websites of resources, which gives you this information (Hegarty Maths). If they do not watch the video, they will be put in a group working on the video's activities in the first part of their in-class learning to catch up.

- Provide institutional supports of operating FC by making sure the school IT team supports both myself, the teacher, and the students.

Results

Power analyses

- Paired t-test pre and post scores: the power returned was 0.89, which means that the test had 89% probability of rejecting the null hypothesis of no difference between means, with a two-sided alternative at a 5% significance level.
- Two-way Repeated measures ANOVA: the resulting power was 87%.

Descriptive statistics

- Pre and post test scores

Time	Count	Mean	Sd
Pre-test score	27	83.70	9.64
Post-test score	27	58.50	20.70

Table 1: Descriptive statistics of average test scores pre and post FCA.

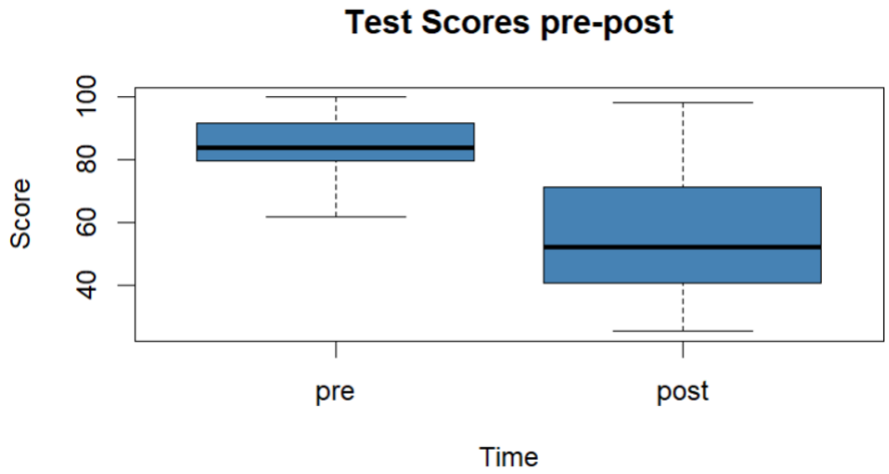

Figure1: Box plot of pre and post FCA raw average test scores.

The test score mean was lower, and the scores were more spread out, after applying FCA (see Table 1). In figure 1 we can see that the interquartile ranges for pre and post test scores do not overlap.

- Questionnaire total scores by classroom approach

Approach	Count	Mean	Sd
Traditional classroom	26	33.38	12.01
Flipped classroom	26	39.92	8.96

Table 2: Descriptive statistics of questionnaire total scores by classroom approach.

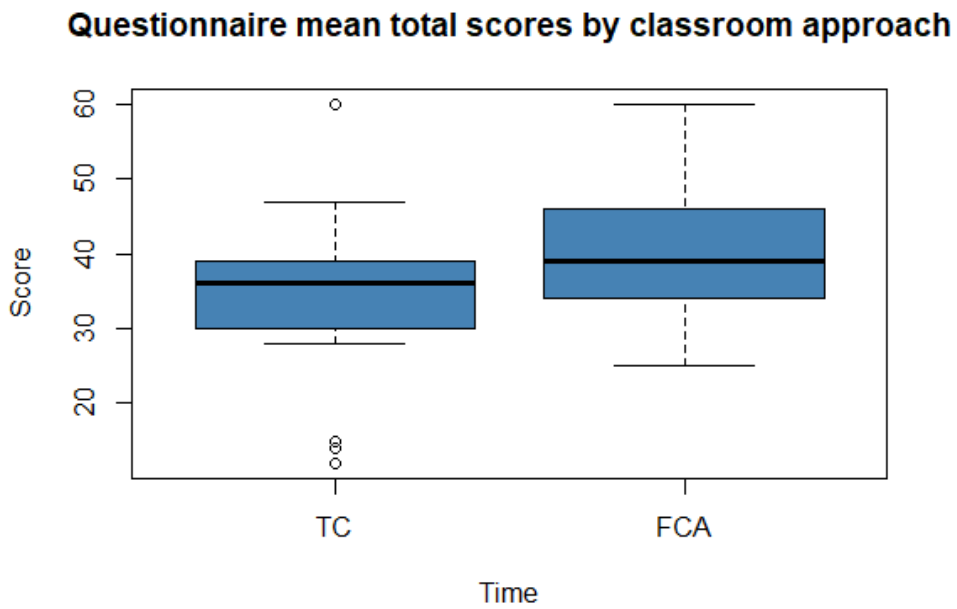

Figure 2: Box plot of questionnaire raw total scores by classroom approach. TC = traditional classroom, FCA = Flipped classroom approach

The flipped classroom approach answered questionnaire showed higher (better) mean total score than the traditional classroom answered questionnaire, with a lower spread (see Table 2). However, the interquartile ranges did overlap (see Figure 2). We can also see some outliers in the

traditional classroom approach scores reflecting the pupils whose attitude was very positive or very negative towards this approach.

- Questionnaire single item response percentage rates by classroom approach

From Table 3 and 4, we can see that in both classroom approach questionnaires (traditional classroom – TC - and FCA), 50% of the students felt motivated to learn maths (item 1), but 50% agreed they are engaged in classwork during FCA lessons, when only 31% felt engaged in TC lessons (item 8). The majority of the pupils agreed that FCA gave time for group activities (81%), while only 12% of the pupils thought that TC offered time for group activities (item 2). Most of the students (88%) believed that they were able to communicate with other students during the FCA lessons (item 9). In contrast, only 27% of the pupils agreed that TC allowed them to communicate with peers. A larger number of students thought that TC improved their maths learning (38%) compared to the number of students believing that FCA improved their learning (27%, item 4). Regarding motivation to do homework (item 6), 38% of the students agreed that they felt motivated to complete the FCA pre-learning homework, while only 27% thought the same about TC.

When naming the advantages of TC lessons in the open question, some students wrote: "more organised", "it's 'more quiet'", "there is a lot of focus", while among the disadvantages of this approach, the students wrote: "no group activities", "it's boring". As improvement for TC lessons, most students suggest more group activities.

Regarding FCA advantages, most of the students' answers were: "communicating with peers", "working in group". The mentioned disadvantages were: "homework is hard", "noisy", "very chaotic". To improve FCA, pupils suggested: "to stop disruption", "better explanation", "better groups", "more work in lesson rather than at home"…

	Traditional classroom (TC) questionnaire item	**Strongly disagree (%)**	**Disagree (%)**	**Neither agree or disagree (%)**	**Agree (%)**	**Strongly agree (%)**
1	I feel motivated to learn maths during TC lessons.	19.23	15.38	15.38	34.62	15.38
2	TC lessons give time to perform group activities in class.	26.92	34.62	26.92	7.69	3.85
3	TC lessons will benefit me in my future education.	19.23	3.85	42.31	26.92	7.69
4	TC lessons have improved my learning of maths.	19.23	15.38	26.92	30.77	7.69
5	In TC lessons I am motivated to regularly do my homework.	26.92	15.38	30.77	15.38	11.54
6	I like watching the Hegarty Maths homework videos entirely when they are on topics already learnt in the lesson.	46.15	15.38	11.54	19.23	7.69
7	I like a traditional teacher led lesson.	19.23	3.85	38.46	26.92	11.54
8	I am engaged in classwork during TC lessons.	19.23	26.92	23.08	19.23	11.54

9	TC lessons give me the opportunity to communicate with other students.	26.92	19.23	26.92	19.23	7.69
10	TC lessons give me class time to practice problem solving.	11.54	15.38	42.31	23.08	7.69
11	I recommend TC lessons to my friends.	15.38	26.92	26.92	15.38	15.38
12	The teacher is able to expand on the topics learnt in TC lessons.	15.38	26.92	30.77	19.23	7.69

Table 3: Single item response percentage rates for traditional classroom approach by scale score (1 = strongly disagree, 2 = disagree, 3 = neither agree or disagree, 4 = agree and 5 = strongly agree). TC = traditional classroom.

	Flipped classroom approach (FCA) questionnaire item	**Strongly disagree (%)**	**Disagree (%)**	**Neither agree or disagree (%)**	**Agree**	**Strongly agree**
1	I feel motivated to learn maths during FCA.	3.85	23.08	23.08	19.23	30.77
2	FC lessons give time to perform group activities in class.	0	7.69	11.54	46.15	34.62
3	FC lessons will benefit me in my future education.	3.85	15.38	50	19.23	11.54
4	FC lessons have improved my learning of maths.	15.38	11.54	46.15	23.08	3.85
5	In FC lessons I am motivated to regularly do my homework.	11.54	11.54	38.46	30.77	7.69
6	I like watching the Hegarty Maths homework videos entirely when they are on topics not yet learnt in the lesson.	30.77	19.23	23.08	7.69	19.23
7	I like a FC lesson, not traditionally teacher led.	11.54	19.23	30.77	15.38	23.08
8	I am engaged in classwork during FC lessons.	0	15.38	34.62	34.62	15.38
9	FC lessons give me the opportunity to communicate with other students.	0	3.85	7.69	30.77	57.69
10	FC lessons give me class time to practice problem solving.	3.85	3.85	46.15	34.62	11.54
11	I recommend FC lessons to my friends.	15.38	15.38	38.46	23.08	7.69

12	The teacher is able to expand on the topics learnt in FC lessons.	11.54	15.38	42.31	23.08	7.69

Table 4: Single item response percentage rates for flipped classroom approach by scale score (1 = strongly disagree, 2 = disagree, 3 = neither agree or disagree, 4 = agree and 5 = strongly agree). FCA = flipped classroom approach.

- Descriptive statistics for Two-way Repeated measures ANOVA

Behaviour	Test	n	Mean score	Sd
0	1.Geomerty	14	87.50	13.12
0	2.Probability	14	85.09	12.77
0	3.Algebra	14	57.14	27.20
0	4.R&P	14	69.14	22.87
1	1.Geometry	13	80.77	18.35
1	2.Probability	13	81.06	12.31
1	3.Algebra	13	42.31	21.51
1	4.R&P	13	64.69	18.28

Table 5: Descriptive statistics of the four consecutive test scores (two pre and two post FCA) by behavioural status (Behaviour = 1 means having behavioural issues). R&P = Ratio and proportion

Pupil premium (PP)	Test	n	Mean score	Sd
0	1.Geomerty	16	88.44	12.61
0	2.Probability	16	86.17	11.60
0	3.Algebra	16	53.98	26.55
0	4.R&P	16	70.81	21.66
1	1.Geometry	11	78.18	18.75
1	2.Probability	11	78.75	12.93
1	3.Algebra	11	44.22	23.36
1	4.R&P	11	61.45	18.27

Table 6: Descriptive statistics of the four consecutive test scores (two pre and two post FCA) by pupil premium (PP) status (PP = 1 means having PP status). R&P = Ratio and proportion

Pupils with behavioural issues had lower means than pupils without per time point (see Table 5), while pupils with PP had lower means than pupils without per time point (see Table 6).

Assumption check

- Paired t-test for pre-post FCA average test scores: The Shapiro-Wilk test null hypothesis of normality of data was not rejected (W = 0.97, p-value = 0.62).
- Paired t-test for questionnaire total scores by classroom approach: The Shapiro-Wilk test null hypothesis of normality of data was not rejected (W = 0.95, p-value = 0.20)
- Two-way repeated measures ANOVA:

Shapiro-Wilk test for normality of test scores by behaviour			
Behaviour	**Test**	**W statistic**	**p-value**
0	1.Geomerty	0.81	0.01
0	2.Probability	0.91	0.17
0	3.Algebra	0.91	0.16
0	4.R&P	0.94	0.45
1	1.Geometry	0.82	0.01
1	2.Probability	0.94	0.40
1	3.Algebra	0.84	0.02
1	4.R&P	0.92	0.24

Table 7: Shapiro-Wilk test for normality of the four consecutive test scores (two test pre and two tests post FCA) by behavioural status (Behaviour = 1 means having behavioural issues). R&P = Ratio and proportion

Shapiro-Wilk test for normality of test scores by pupil premium			
Pupil premium (PP)	**Test**	**W statistic**	**p-value**
0	1.Geomerty	0.79	<0.01
0	2.Probability	0.92	0.16
0	3.Algebra	0.88	0.04
0	4.R&P	0.94	0.33
1	1.Geometry	0.83	0.03
1	2.Probability	0.96	0.81
1	3.Algebra	0.91	0.22
1	4.R&P	0.94	0.53

Table 8: Shapiro-Wilk test for normality of the four consecutive test scores (two test pre and two tests post FCA) by PP status (Behaviour = 1 means having behavioural issues). R&P = Ratio and proportion, PP = pupil premium.

The null hypothesis of normality was only rejected for the geometry and algebra test scores within categories of behaviour (see Tables 7 and 8). This could be due to small sample size.

Paired t-test results

- The paired t-test comparing average test scores pre-post FCA returned a statistic of t = 7.7724, df = 26, with p-value <0.0001, indicating that the mean score difference of 25.22, 95% CI 18.55 to 31.89, was statistically significantly different from zero. Therefore, my year 10 higher achiever students performed better in a traditional classroom environment than in a flipped classroom environment.

- The paired t-test comparing questionnaire total scores by classroom approach returned a statistic of t = - 2.03, df = 25, with p-value = 0.05, indicating that the mean score difference between questionnaire scores about TC and scores about FCA (-6.54, 95% CI -13.17 to 0.09) was borderline statistically significantly different from zero. Thus, pupils had better attitude towards FCA compared to TC, but this difference was not statistically significant.

Two-way repeated measures ANOVA results for behaviour

Effect	Dfn	Dfd	F-statistic	p-value	p < 0.05	ges
Behaviour	1	100	4.20	0.04	*	0.04
Time	3	100	19.56	< 0.000000001	*	0.37
Behaviour : Time	3	100	0.47	0.70		0.01

Table 9: Two-way repeated measures ANOVA results. The test scores are the dependent variable, time (4 time points corresponding to the 4 consecutive end of unit tests the pupils completed in two terms, 2 pre and 2 post FCA) and behaviour are the between-subject factors. Also their interaction (Behaviour : Time) is considered. Dfn = F statistic degrees of freedom in the numerator, Dfd = F statistic degrees of freedom in the denominator, ges = generalized effect size (amount of variability due to the within subject factor, which is ID, variable identifying pupils).

Two-way repeated measures ANOVA results for Pupil premium (PP) status

Effect	Dfn	Dfd	F-statistic	p-value	p < 0.05	ges
PP	1	100	6.13	0.02	*	0.06
Time	3	100	18.93	< 0.000000001	*	0.36
PP : Time	3	100	0.03	0.99		< 0.01

Table 9: Two-way repeated measures ANOVA results. The test scores are the dependent variable, time (4 time points corresponding to the 4 consecutive end of unit tests the pupils completed in two terms, 2 pre and 2 post FCA) and PP are the between-subject factors. Also their interaction (PP : Time) is considered. Dfn = F statistic degrees of freedom in the numerator, Dfd = F statistic degrees of freedom in the denominator, ges = generalized effect size (amount of variability due to the within subject factor, which is ID, variable identifying pupils).

There was strong evidence against the null hypothesis that the test score were not different between time points in both analyses: F(3, 100) = 19.56 for behaviour, p < 0.0001, η^2 = 0.37; and F(3, 100) = 18.93 for PP, p < 0.0001, η^2 = 0.36 (see Tables 8 and 9).

Behaviour had a borderline statistically significant (F(1,100) = 4.20, p = 0.04, η^2 = 0.04) effect on scores, with pupils having behaviour issues scoring less than pupils without, independently from the FCA intervention (see Table 8).

There was no evidence for an interaction (p = 0.70) between effects of behaviour and time (see Table 8).

PP had a statistically significant effect on scores (F(1,100) = 6.13, p = 0.02, η^2 = 0.02), with pupils having PP scoring less than pupils without regardless of the FCA intervention, with a poor effect size η^2 = 0.02 (see Table 9).

There was no evidence for an interaction (p = 0.99) between effects of PP and time (see Table 9).

Discussion and conclusion

In the present study, there was no evidence that FCA improves progress in maths in my year 10 high achiever pupils. Instead, FCA worsened the students' end of unit test results compared to traditional classroom. There was no evidence that behaviour and pupil premium status modified the effect of the intervention on the test scores. However, students had more positive attitudes towards FCA compared to TC, but this difference was not statistically significant.

This result contrasts with the literature on FCA, and might be due to the limitations of the study:

- Small sample size to detect an effect of behaviour modifying the effect of the intervention on scores.
- The topics of the tests were too different from each other, and it is known that, for example, the unit on algebra (straight lines) is always more challenging for students than other units.
- The teacher was unexperienced in behaviour management to conduct group activity (I am an early career teacher in my first year as a qualified teacher), as pupils have complained about in the questionnaire.
- The pupils did not take advantage of the afternoon sessions offered in case of no understanding of the topic.
- Year 10 students are younger than some of the student cohorts recruited in other FCA studies.

To conclude, implementing FCA in a year 10 class requires strong behaviour management skills to make sure pupils are engaged in classwork and learn. Teachers need to thoroughly prepare the FCA sessions considering all possible misconceptions arising from students' pre-learning at home.

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