# Flipped Learning in Secondary School Mathematics- Is It Worth the Flip?


## Abstract

There is a growing argument that the traditional method of teaching maths is ineffective at developing fluent and adaptive mathematical skills (Boaler et al., 2015; Weiss & Pasley, 2004), resulting in disengaged and dissatisfied students (Boaler et al., 2015; Brown et al., 2008; Clark, 2015; Nardi & Steward, 2003). Flipped learning provides an alternative pedagogy, whereby digital instructional content is digested by students before lessons, freeing-up in-class time for more engagement with teachers and peers on real-life maths problems, promoting higher-level thinking skills (Bergmann & Sams, 2012). In this critique, theories underpinning flipped learning are described and a systematic search of the evidence-base exploring the effectiveness of flipped learning as a maths pedagogy for students aged 11-16 years is conducted and reviewed. Implications for using flipped learning in educational practice are discussed, including implications following the COVID-19 pandemic. With education experiencing unprecedented challenges since 2020 due to national lockdowns, increased student and teacher self-isolation, and reduced time in the classroom, the potential of flipped learning is considered as an alternative or additional supplement to traditional maths teaching.

In 2019, only 43.2% of UK pupils in state schools achieved a grade five or above in GCSE English and Maths (Department for Education, 2020). Despite expectations that students exiting Key Stage 4 should have developed skills in mathematic fluency, reasoning and number problem-solving (Department for Education, 2014), statistics show that 49% of adults have the numeracy level equivalent to a primary-school-aged child (National Numeracy, 2018). This suggests a 'maths crisis' in the UK (Boaler et al., 2015), but does this reflect poor maths retention in adulthood or deficient original learning of maths skills?

There is a growing argument that the way maths is taught in schools is ineffective at developing fluent and adaptive maths skills (Boaler et al., 2015; Weiss & Pasley, 2004). In traditional teaching, concepts are taught via teacher instruction followed by classroom activity. The greater factual content in maths may increase passive learning experiences for students, with teachers spending approximately 63% of lesson time delivering instructional content to the class (Schwerdt & Wuppermann, 2011), contributing towards poor student achievement (Weiss & Pasley, 2004). Traditional teaching is also criticised for being 'teacher-centred', educating students in an "assembly line manner" (Bergmann & Sams, 2012, p.6), resulting in disengaged and dissatisfied students and poor math achievement (Boaler et al., 2015; Brown et al., 2008; Clark, 2015; Nardi & Steward, 2003). This has paved the way for a new pedagogy which combines technology, collaboration and experiential learning, that is said to engage students more so than traditional methods (Phillips & Trainor, 2014), called flipped learning.

**What is flipped learning?**

Flipped learning is defined as "a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space" with in-class space being "transformed into a dynamic, interactive learning environment" (Flipped Learning Network, 2014). Flipped learning was introduced into American high schools in 2006 by teachers, Bergmann and Sams (2012). They proposed ‘flipping’ the classroom by providing instructional videos for students to digest before class, freeing up in-class time for students to practise applying knowledge and skills with peers, rather than in isolation via homework. They recommended that students engage in quizzes at the end of online instruction or at the beginning of lessons, so that teachers can gauge understanding levels and group students accordingly into differentiated activity groups.

Flipped learning is said to ultimately enable teachers to spend more time in class: using a student-centred approach (Kong, 2014), answering questions “just in time” (Roach, 2014) whilst students are applying concepts, and giving students more opportunities to engage collaboratively (Marbach-Ad & Sokolove, 2002). These techniques enhance student engagement (Fulton, 2012) and support academic growth (Siegle, 2014). The self-paced nature of online content, which can be paused/rewound/skipped-over based on levels of understanding (Fulton, 2012; Hamdan et al., 2013; Roach, 2014), also provides students with learning autonomy (Hamdan et al., 2013) and reduces cognitive load (Abeysekera & Dawson, 2015).

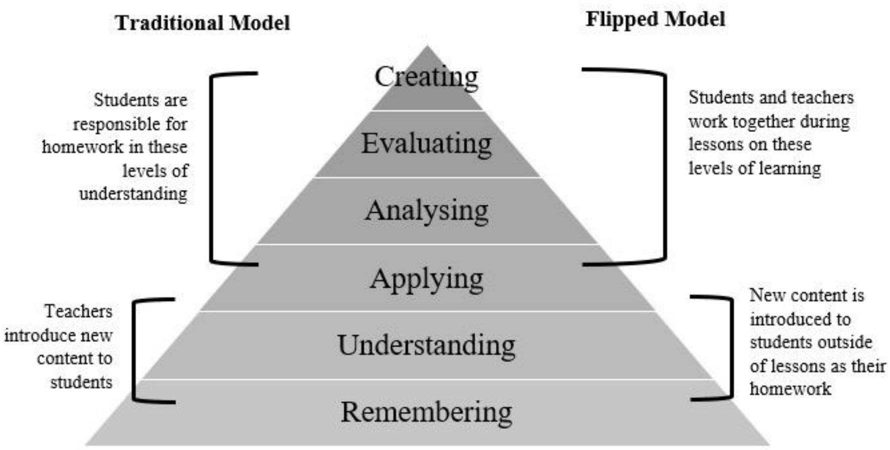
The popularity of flipped learning has increased in the last decade (Goodwin & Miller, 2013) with a “flipping revolution” (Neshyba, 2013) occurring, particularly in higher education and American schools (Flipped Learning Network, 2014). The Flipped Learning Network reported that 78% of teachers had tried flipping at least one of their lessons and 96% would recommend flipping to others (Flipped Learning Network & Sophia, 2014). Flipped learning may be particularly useful for Science, Technology, Engineering, and Maths (STEM) disciplines which have higher levels of instructional content compared to discussion-based subjects, such as humanities (Bergmann & Sams, 2012; Oyola, 2016).

**Theories underpinning flipped learning**

Flipped learning is commonly referenced in relation to the cognitive domain of Bloom's taxonomy (Bloom et al., 1956). In the revised Bloom's taxonomy (Anderson et al., 2001), students master learning goals of remembering, understanding, applying, analysing, evaluating, and creating. Flipped learning shifts the levels that are traditionally gained from in-class instruction (remembering and understanding) out of the classroom, making space for higher-order thinking skills at the upper end of the taxonomy to be developed in class (see Figure 1) (Bergmann & Sams, 2012). This 'flip' of Bloom's taxonomy is particularly useful in mathematics teaching (see Talbert, 2019, for a detailed account).

Figure 1.

*Comparison of the application of flipped learning model compared to traditional teaching, using the revised Bloom's taxonomy (Bloom, 1956).*




The collaborative focus during class time can be seen as being grounded in the constructivist theory of learning, which advocates that meaningful and deeper understanding of concepts can only occur when a student is in an engaging and collaborative learning environment (Vygotsky, 1978). Constructivists argue that traditional teaching "promotes neither the interaction between prior and new knowledge nor the conversations that are necessary for internalisation and deep understanding" (Richardson, 2005; p.3). The increased face-to-face time in flipped classrooms enables students to build closer relationships with their peers and teachers, resulting in more interactive and meaningful learning experiences (Roach, 2014). By interacting with students, who are also constructing their own knowledge, students in the flipped classroom can share ideas and use higher-order thinking skills to argue their thinking (Ding et al., 2007).

Principles of constructivism also highlight the importance of scaffolding within a student's zone of proximal development (ZPD; Vygotsky, 1978) which can support the development of higher-level maths skills (Katsa et al., 2016; Watson & De Geest, 2005). The additional time in-class and increased interaction in a flipped classroom can help students take on more tasks that are within their ZPD, compared to traditional teaching.

Finally, constructivism states that learning best takes place through authentic tasks (Honebein, 1996). In the flipped learning model, authenticity is brought into learning via teacher-developed videos and in-class problem-solving activities that relate to real-life experiences (Sams & Bergmann, 2013). By engaging in authentic maths problems, students "learn about the value of mathematics in society and its contributions to other disciplines" (p. 155; Anthony & Walshaw, 2009) resulting in a greater appreciation and interest in maths. However, this isn't unique to flipped learning and real-life problem-solving can, of course, be utilised in traditional teaching methods as well.

**Evidence base for flipped learning maths teaching**

There are reviews of flipped learning in relation to secondary school education (see Lo and Hew, 2017) but there is currently no review of its effectiveness for maths education for this age group. Therefore, a systematic search was used to explore the effectiveness of flipped learning in maths with students aged 11-16 years. A search of databases PsychInfo, ERIC, Web of Science, and Proquest yielded a return of 64 studies of which 53 were excluded due to the study not meeting inclusion criteria (e.g., participants outside of stipulated age range, intervention not explicitly focussed on flipped learning, insufficient quantitative data, maths attainment not an identified outcome measure, or no comparison group) resulting in 11 studies for detailed analysis. Whilst nine studies concluded that flipped learning did significantly improve maths attainment compared to traditional teaching (TT) (Bhagat et al., 2016; Biederman, 2018; Esperanza et al., 2016; Lo et al., 2018; Lo & Hew, 2020; Njeru, 2020; Rahman et al., 2018; Wei et al., 2020; Yousefzadeh & Salimi, 2015), one found significant improvements only in certain elements of maths (Kirvan et al., 2015) and another, no significant improvement (Clark, 2015).

Rahman et al. (2018) concluded that, after two weeks of flipped learning, Malaysian students performed significantly better on a statistics test compared to peers receiving TT ($R^2$= 0.64). Similarly, Njeru (2020) and Biederman (2018) reported significant differences in Algebra 1 achievement between 9$^{th}$ grade flipped learning and TT students, following two and three weeks of teaching respectively (*d*= 0.676 and *d*=4.402). However, the pre- and post-tests were the same in both studies, therefore familiarity bias may have influenced results, although we would expect to see improvement in both groups. The duration of these studies can be interpreted in two ways. On the one hand, attainment improvement after such a short period of time could be a testament to the power of the pedagogy. Alternatively, the duration could be a limitation, as the researchers are unable to evidence long-lasting acquisition of maths skills.

Esperanza et al. (2016) addressed this limitation by conducting a study spanning a whole academic year, concluding significant superior maths performance by flipped learning students compared to controls (*d*= 0.43). Longitudinal studies are useful, especially when findings can influence educational practice, however they can also incur confounding variables, such as the length of time risking students receiving additional maths support elsewhere, making it difficult to establish whether the effect was truly as a result of flipped learning.

In Hong Kong, Lo et al. (2018) concluded a significant positive effect of flipped learning on 9th grade students' maths performance (*d*=0.337). However, researchers acknowledged that complex maths concepts were taught using traditional instructional methods, invalidating the experimental group as being entirely 'flipped'. Lo and Hew (2020) also incorporated gamification into flipped learning, comparing it against online study with gamification alone and TT. Their findings indicate that maths enrichment students in the flipped class scored significantly higher than those receiving TT or online study only (*d*= 0.3773 and *d*= 0.5119 respectively). However, the lack of an experimental group without gamification makes it difficult to decipher the effectiveness of flipped learning as a pedagogy.

Exploring flipped learning with students of varying ability, Bhagat et al. (2016) categorised trigonometry students into low, average and high-ability and found that students in the flipped class outperformed students receiving TT post-test (η2 =.092). They also reported a significant difference post-test for all abilities except high achievers, however average ability students (flipped and TT) were reported to be significantly different at pre-test. This suggests that flipped learning may be particularly helpful for low-ability students, with pre-teaching via video allowing for increased support from teachers during lessons (Bhagat et al., 2016). Therefore, it is not the video element that supports lower-ability students but the increased availability of high-quality teaching the flipped learning model provides.

Kirvan et al. (2015) studied student ability to analyse, model and solve systems of linear equations and concluded that flipped learning only significantly improved students' ability to solve (*d*=0.69), not to model or analyse maths problems. This suggests that flipped learning may not be as efficacious for the development of higher-level thinking skills as advocates propose. Wei et al. (2020) concluded that flipped learning had a significant positive effect on student ability to understand ‘rational number and its operations’ compared to TT however, they did not report an effect size. Yousefzadeh and Salimi (2015), reporting a significant positive effect of flipped learning, also did not report effect size and confidence intervals. This makes it difficult to ascertain the size of the positive effects reported and compromises the quality of these studies (Sullivan & Feinn, 2012).

Finally, Clark's (2015) research was the only study to conclude no significant difference in achievement between 9th grade flipped and TT groups, following 7 weeks of teaching. Of note however, is that this study did not report key elements in detail which meant that it scored poorly in terms of overall quality.

Due to the educational setting, many studies utilised a quasi-experimental design as researchers were unable to randomly allocate participants to experimental and control groups (Bhagat et al., 2016; Biederman, 2018; Lo et al., 2018; Lo & Foon Hew, 2017; Njeru, 2020; Wei et al., 2020). This is a limitation given the research focus on exploring the efficacy of one pedagogy over another, however an appropriate ethical decision. Future researchers could consider using a waiting list control group as an alternative. Many researchers were also unable to blind participants and researchers due to participants attending the same school or the researchers delivering the intervention themselves (Bhagat et al., 2016; Biederman, 2018; Clark, 2015; Esperanza et al., 2016; Kirvan et al., 2015; Lo & Hew, 2020; Njeru, 2020; Rahman et al., 2018; Wei et al., 2020; Yousefzadeh & Salimi, 2015).

Finally, generalisation of findings to a UK population may be limited, especially given the difference in sequential maths courses delivered in the USA (Algebra, Geometry, Trigonometry etc.), which can be re-taken, compared to the UK maths curriculum, which constitutes an amalgamation of all maths skills under one linear subject of ‘Maths’.

**Implications**

Whilst studies of short (Rahman et al., 2018; Biederman, 2018) and long duration (Esperanza et al., 2016) reflect positive outcomes on maths attainment, teachers need to consider how useful a brief implementation of flipped learning will be for maths skill development, especially as maths topics are not taught sequentially in the UK. Those contemplating a longer ‘flip’ of maths teaching should also consider impact on workload, given the time it takes for teachers to prepare and create high-quality video content and lessons (Herreid & Schiller, 2013; Lo & Hew, 2017).

For flipped learning to be successful, teachers must be experienced and confident with the pedagogy and feel supported by senior management (Lo & Hew, 2017). Quality of videos will need to be routinely reviewed, however having access to a bank of teacher-produced content could make moderating and monitoring fidelity manageable as well as examples of high-quality videos being a useful CPD opportunity for teachers who are less experienced with multi-media teaching methods.

Teachers should also consider if flipped learning is right for their students, based on their ability and topic content. For a low-ability maths class, flipped learning might yield positive results (Bhagat et al., 2016) but only due to the extra direct teacher time they receive in class. More complex maths concepts may be better taught using traditional methods, as in the case of Lo et al. (2018), suggesting that flipped learning may serve as “more of a compliment, rather than a substitute" (Roach, 2014, p.75) to traditional teaching.

Student engagement with online videos is crucial if they are to benefit from subsequent in-class learning. It is also important to note that only access of videos is differentiated (e.g. being able to pause and rewind), not the content itself, risking disengagement of some students if they do not understand the content of the video. How video content can be differentiated for varying abilities, including SEN students, will need continued exploration.

Students also need to be supported to learn how to adapt to the flipped learning style and consideration must be given to the additional time pressures this will incur for students (Barbaro, 2019; Lo & Hew, 2017; Yildirim, 2017; Zhai et al., 2017). It may be challenging for students to learn how to engage in a new pedagogy alongside learning content (Clark, 2015), therefore pre-teaching of the flipped learning concept would be valuable (Kirvan et al., 2015). Exploring student experience and perceptions of flipped learning will also be important, however this was beyond the scope of this review.

Another concern is digital equity, as not all students will have access to technology to watch online videos at home (Bull et al., 2012). The difficulties providing suitable technology for students has been particularly highlighted as a result of the COVID-19 pandemic (Ferguson & Walawalker, 2020). In order to address digital inequity, practitioners should consider giving students access to technology during the day (e.g. free study periods before, during or after school) or alternative means of instruction such as CDs (Bergmann & Sams, 2012).

Whilst flipped learning may be costly in terms of time and equipment, these short-term costs could result in longer-term benefits for student engagement and learning, especially in STEM subjects. However, this would require a significant culture shift within the UK education system, for example flipping the understanding that homework (watching instructional videos) is to be completed before class, rather than afterwards.

***Implications in light of the COVID-19 pandemic***

Since 2020, educators have experienced unprecedented challenges because of the COVID-19 pandemic. In response to national lockdowns, social distancing and increased staff and student self-isolation (Tidman, 2020), schools have had to embrace what online technology can add to traditional teaching. If in-classroom time continues to be limited for some, utilising the ‘flip’ of Bloom’s taxonomy may support students to develop understanding and recall of maths concepts at home, therefore making the most of the available face-to-face time with teachers to ask questions and receive feedback and experience differentiated and greater-depth activities with their peers.

## Conclusion

Flipped learning may provide an alternative way to teach maths, yielding positive academic results and the mastery of higher-level thinking skills, which are applicable to real-life. Despite methodological issues, studies have highlighted the positive influence flipped learning, ranging from weeks to a whole academic year, can have on student attainment. However, questions remain around the pedagogy’s effectiveness at teaching certain elements of maths. Further research is needed to explore the use of flipped learning in UK schools. Those considering implementing flipped learning must be aware of implications in terms of teacher time, student understanding of how to engage in flipped learning, and digital equity. Given the on-going challenges relating to COVID-19, flipped learning may also provide students and teachers with an effective pedagogy that is both engaging and accommodating, helping to work towards re-engaging students’ learning and passion for mathematics.

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