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A supported flipped learning model for mathematics gives safety nets for online and blended learning

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ABSTRACT

Flipped learning is a popular pedagogy, and its benefits, challenges and implementations have recently been discussed widely. This study presents the implementation of a new 'supported' flipped learning model for teaching foundation-year mathematics, built on mathematics anxiety principles. Effective flipped learning requires a good course structure, and therefore the purpose of this study is to explore student perspectives and experiences of the structure of the supported flipped learning model. Interviews were carried out with students who took a foundation mathematics module between 2016 and 2021 ($n = 34$), including cohorts who experienced it in blended forms and entirely online. One overarching theme of structure and online working encapsulates six themes forming the discussion: 'timing is important'; 'structure of materials'; 'online enables access'; 'distractions online and at home'; 'finding online difficult'; and 'better than traditional teaching methods'. The results show that students from a range of disciplines, including non-STEM (science, technology, engineering, and mathematics) courses, are positive about the supported flipped learning model for studying mathematics, believing it superior to traditional teaching methods. The structure of this model gives students a sense of progression while providing a safety net for students with lower levels of self-regulation who often find flipped environments challenging. The structure of lessons, the materials used, and delivery infrastructure are crucial to success. The new model presented here advances current use of flipped learning for mathematics, and potentially other subjects, in higher education. The structure has also been shown to be appropriate for rapid transition to online learning.

1. Introduction

This paper explores interviews with students on a range of higher education (HE) degree tracks who studied foundation-level mathematics. Students were asked about their experiences of a new 'supported' flipped learning model for maths teaching, which was developed building on principles of maths anxiety reduction.

1.1. Flipped learning

Flipped learning, also known as a flipped classroom or inverted classroom, is a pedagogical approach where the typical classwork (e.g. content delivery) is instead done at home, and typical homework activities (e.g. problem-solving consolidation questions) are done during class time [1, 55]. This results in a student-centred, active learning environment with the educator as a facilitator rather than being the centre of the activity [16, 55]. Within this definition, there are a number of ways a flipped classroom can be structured, and the structure of a flipped learning course is considered one of the primary factors that affects its effectiveness [7, 29].

One aspect of course structure is infrastructure, which includes the organisation of topics and materials and ease of access and use, particularly for online environments [7, 29]. A second aspect is the educational objectives of the course, which encompasses not only explicit objectives, but teaching strategies, workload and assignments [29]. Under this falls the type of materials and interactions students experience on their course. Some authors (e.g. [9]) suggest that flipped content material must be computer-based in the form of video lectures, and non-video content cannot be considered flipped learning. While this definition does differentiate flipped learning from traditional methods of

Abbreviation: BBC, British Broadcasting Corporation; BIDMAS, brackets, indices, division, multiplication, addition, subtraction (order of operations in mathematics); COVID-19, coronavirus disease 2019; GCSE, General Certificate of Secondary Education; HE, higher education; VLE, virtual learning environment.

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class preparation where the student is asked to read a textbook chapter or a journal article before a lesson, it is unnecessarily stringent, particularly for mathematics where specific preparation reading is rarely assigned. Lo and Hew [31] expand upon Bishop and Verleger's definition by including audio or video materials, with a further criterion of regular, non-optional face-to-face lessons. This study agrees with He et al. [24] who suggest that putting constraints on the type of learning material is "unnecessary and unjustified" (p. 61), with low-tech flipped methods such as readings supported by worksheets being effective in their own right [38]. However, particularly in mathematics education, readings may not be as effective as videos, where these are available [51].

Past studies have found that flipped learning has many benefits for students, including increased performance [1, 8, 32, 50], increased engagement and motivation [6, 48], increased self-regulation [58], increased student autonomy [2, 39], increased student collaboration [63], increased creativity [25], higher course satisfaction [27], and increased effectiveness of soft skills [8]. Flipped learning can achieve the same student outcomes as traditional courses with less "seat time" (p. 227), meaning that there are opportunities for flipped classrooms to enhance the efficiency of higher education learning by reducing the amount of staff-student contact necessary [4]. This contact time could also be used to provide more individual help [6, 19]. Flipped methods offer increased opportunities for problem solving, particularly using the application of new knowledge [15], and students found this more enjoyable than traditional teaching approaches [6]. This may, however, simply be due to a more active classroom environment which students find more interesting than passively listening to lectures [19]. Students also feel that flipped learning helps them to be more prepared for class [31, 51] and they could learn at their own pace [31]. Educators using flipped learning often choose it to increase students' engagement and self-regulation, as well as providing a more individualised learning experience [62]. In higher education specifically, meta-analyses have shown that flipped learning increases academic performance, and that this has increased in more recent years, suggesting that the development of effective flipped pedagogies is improving (K.-S. [17]). Within mathematics in particular, it has been found that flipped learning, in addition to the above benefits, reduces students' mathematics anxiety ([70]), although this has also been identified as a topic for further, more rigorous, study [33].

However, some studies have shown that there is little difference between flipped and traditional learning in terms of overall students' outcomes and effectiveness [21, 44], or that it even has negative effects [28]. Some studies have found that flipped learning only, or at least mostly, benefits the less able students [20, 49]. Several studies [27, 40, 45] found that students with high levels of self-regulation are more likely to benefit from a flipped learning design, and therefore those with lower self-regulation may struggle. However, flipped learning can foster in students a more self-regulatory approach to their own learning [58]. One of the most common concerns with flipped learning is a reliance on student engagement with pre-class activities, and this is a particularly common problem in compulsory-school-level teaching [31, 34]. Some students feel that the amount of pre-class work is overwhelming [54, 57]. They may also experience boredom or difficulty watching long videos [54], which may also arise from attempting to watch too many short videos in one sitting [57]. However, the studies that report this as a problem are almost all from a pre-HE setting, which suggests that trouble engaging with material before the class may not be something that university students struggle with, or admit to struggling with. On the other hand, a study done in the "world's first fully flipped university" ([7], p. 1) suggests that some students do struggle to engage with pre-lesson material, particularly longer videos, although this was based on faculty perceptions rather than student views [7]. Studies have also found that teachers either struggle to find an appropriate third-party video to cover the topic they want, or that they have to create videos themselves, which they find to be extremely time-consuming (L.-L. [18, 57]).

In order to shed clarity on the uncertainty surrounding the effectiveness of flipped learning, Shi et al. [55] and Sablan and Prudente [50] carried out more recent meta-analyses. Sablan and Prudente [50] found a strong effect size for flipped learning increasing academic performance of mathematics students across several phases. Shi et al.'s [55] study focused on higher education specifically, and found that compared to a traditional lecture format, flipped learning positively affects HE students' learning outcomes across the literature. Furthermore, the study examined several potential moderator variables and determined that the flipped pedagogy was the only variable to significantly affect the result, further implicating that the positive learning outcomes were entirely due to the flipped learning method [55]. No publication bias was found in the Shi et al. [55] meta-analysis for flipped in HE, nor the meta-analysis conducted by Lo et al. [34] for mathematics education; however, another meta-analysis conducted by Zhu [69] found that publication bias was present across the flipped literature, although this was done for school-age classrooms and not higher education which may account for the difference.

Overall, it is clear that the majority of studies show support for flipped learning being an effective pedagogy that benefits many students in a variety of ways. The structure, in terms of educational objectives and infrastructure, is also important, as this underpins the quality of the rest of the course.

1.2. Problem statement and purpose of the study

Although flipped learning is widely considered applicable for science, technology, engineering, and mathematics (STEM) courses in particular ([5]; K.-S. [17, 23]), many of the studies in mathematics are based in secondary schools, not higher education (e.g. [6, 11, 36, 53]). There are even fewer studies that look at flipped foundation mathematics courses in higher education, with only two identified by the author of this study [3, 59], which prepared students specifically for mathematics, computing and engineering courses. No studies were found about foundation mathematics modules that are taken by students who are on degree tracks outside STEM fields, as this is relatively unusual. However, students who are studying social sciences are more likely to experience mathematics anxiety, and students who do experience maths anxiety are less likely to choose further study or work that includes mathematics elements [37]. The purpose of this study therefore is to explore student perspectives on the new supported flipped learning model presented here, where the students are from a range of degree tracks.

The flipped model is further applicable to the wider context of teaching mathematics in higher education, and it may have value to educators outside mathematics as well. It is important to assess students' experiences of the new model in order to understand whether it has been successful as an engaging and useful pedagogy for students. It is also useful to understand how flipped learning can be used within mathematics, as well as how it can potentially be used in other disciplines with or without mathematical aspects since views about course structure tend not to vary between disciplines [7]. This study presents a model that reduces maths anxiety that educators may wish to consider for their own teaching in higher education.

This study was conducted within a constructivist perspective, where knowledge is constructed individually and is not necessarily based on an ontological truth [66]; participants, therefore, represent their interpretation of reality, which is subsequently analysed through the researcher's interpretation.

To this end, the following research question was asked: What are students' perspectives and experiences of the structure of the supported flipped learning model?

2. Methods

This section presents the context of the study, information about the participants and ethics, how the data was generated, the instrument used, and how the data was analysed.

2.1. Context

The study was based at a Russell Group university in the North of England. The university offers a foundation year for undergraduate students going on to a range of different degrees across the disciplines of the sciences, social sciences, arts and humanities, and medicine, dentistry, and health. The foundation year is an integrated year within their degree; in practice, this means that as long as students achieve a "progression" mark (usually 60%) across their foundation-level modules, they are guaranteed progression onto level one of their chosen degrees. The foundation years for all subjects are delivered together on a full- or part-time basis within a separate foundation-level department, after which students join their destination departments. The students on these degrees with foundation year are usually education returners who have gained life and work experience and skills, and often lack traditional entry requirements such as A-levels or GCSEs. However, it is also worth noting that some students came to the department with very high levels of qualifications and had disrupted studies for other reasons, such as personal illness, caring responsibilities, or simply realising they weren't yet ready for higher education at a younger age.

The foundation year for all students comprises of several modules. This includes a GCSE-level 'Maths and Statistics' module that is compulsory for all students, regardless of their degree track. This module was designed and delivered by an expert tutor (the author of this paper) based on research-led mathematics anxiety principles ([70]) and a desire to engage students who may be otherwise unengaged with mathematics, such as those on arts and humanities degree tracks. Maths anxiety is defined as "a condition characterised by negative reactions (e.g. fear) towards mathematical tasks" ([14], p. 67). The foundation students in the target department had previously been found to have much higher levels of mathematics anxiety than the rest of the student population in the wider university ([70]). The supported flipped learning structure was therefore created to address this anxiety and provide a supportive environment for all students. The statistics section of the course was delivered in a slightly different fashion by other members of staff who taught on the module, so this study focuses only on the mathematics aspects of the module.

2.2. Introduction of the supported flipped model

The supported flipped learning model presented in this paper was taught for the first time by the tutor in 2016, developed further in 2017 and 2018, and delivered by the tutor each year until the tutor left the institution at the end of the 2020–21 academic year. Delivery in the 2019–20 year was interrupted by the first COVID-19 lockdown, with lessons being moved online for the final six weeks of the course. The subsequent year, 2020–21, was held entirely online.

The first session of the year was a mathematics anxiety workshop. Making students aware of their mathematics anxiety and introducing strategies to address this is important in reducing this anxiety ([70]; [64]). Following the mathematics anxiety workshop, the tutor ran a tutorial session which took the time to explicitly explain the flipped learning structure, the rationale behind it, and the associated expectations to students. This was to reduce student confusion about the learning arrangement, since this confusion can reduce the effectiveness of flipped learning [19, 54, 57]. The aims of the supported flipped model presented in this study are to reduce students' mathematics anxiety, provide high flexibility for students who are often parents or carers, provide additional support for students, and to provide a safety net for the most vulnerable students.

The teaching structure was the same format every week so to maintain consistency and reduce confusion for students. This in turn reduces their mathematics anxiety by reducing their cognitive load [47] and provides them with a framework upon which they can arrange their lives, which is particularly important for foundation year students. The flipped materials were given online on the virtual learning environment (VLE) two weeks in advance of the lesson. Each week's topic (e.g. BIDMAS) was broken down into subtopics (e.g. adding and subtracting negative numbers; multiplying and dividing negative numbers; using brackets; indices; and BIDMAS itself). The tutor added instructions on the VLE each week explicitly reminding students that it was up to them to judge their own learning needs, and that they could use the Numbas quizzes to help them judge how they were doing [27]. The lessons themselves consisted of a one-hour interactive session followed by a one-hour tutorial. For in-person teaching, the one-hour interactive session was duplicated, with half of the cohort (usually approximately 80 students) attending one of the two sessions. There were three to four tutorials each week, each containing around 40 students, and students attended one of the tutorials, although they could attend additional tutorials if they felt they needed it. During the pandemic, the interactive session was run once with all students in the cohort attending online for the one session. There were four tutorial sessions, and again, these were all run online.

The interactive session was designed so that students had a middle step between looking at the flipped materials on their own and attempting to answer questions on them in a tutorial scenario. Traditional flipped learning tends to have these as the only two steps, although quizzes to check students have done the flipped work, and short review lectures with the opportunity to ask questions may also part of the in-class activities [41]. The supported flipped model presented by this study hoped to bridge the gap between home-learning and the exam-style short-answer questions that formed the tutorial by holding the question-answer session and quizzes as a separate class with multiple-choice questions specifically. In order to add an additional layer of support, a lot of emphasis was put on anonymity at this middle stage so that students felt able to ask the questions they wouldn't have felt comfortable asking in front of the whole cohort [61], and got to practice the multiple-choice questions anonymously as well. This stepwise increase in difficulty from online content to interactive session to tutorial in three steps is the main way that this supported model differs from previous flipped learning models. Table 1 gives more details on the structure of the three sections of the supported flipped learning model.

2.3. Participants

This study used purposive sampling. Students who completed their foundation year between 2017 and 2021 were emailed to invite them to volunteer for interviews about their experiences of the supported flipped learning course. Only students who had completed their foundation year and left the department were invited as they had full experience of the course. They were sent an information sheet detailing the aims of the study, how their data will be used and protected confidentially, and potential risks and benefits of participating. A reminder of the structure of the flipped learning course was also included. Participants were asked to book a slot using Google Calendar if they were interested in being interviewed. A prize draw for one of two £10 Amazon vouchers was offered to thank them for their time.

271 foundation-year students were invited to participate, chosen using a random number generator from a total of 447 students who were still at the university. It is worth noting that email invitations were sent during exam periods and summer holidays due to the tutor's availability, which may limit the response rate. Initially, 41 students signed up for an interview, of which 7 were not interviewed for various reasons (illness, absence, etc.) and did not reschedule.

In total 34 students (12.5% of the invited students and 7.6% of the available cohort) were interviewed (20 female, 14 male). The

Table 1
Structure of the flipped learning model.

Flipped model section	Activity	Rationale
Online flipped learning materials	PowerPoint slides for each subtopic – explanation and examples.	Learning is accessible in more digestible chunks to reduce feelings of being overwhelmed, gradually desensitising students to the maths, and allowing students to be flexible and self-paced in their learning [9, 10, 47, 54, 68].
	Informal, tutor-created YouTube videos of example working, each approximately 5 min long.	Important to keep videos short, ideally under 15 min [54]. Modelled a laid-back positive attitude for mathematics, helping to reduce maths anxiety [67].
	Third-party YouTube videos of alternative explanations and alternative methods.	Provides more options for students who are struggling and reduces maths anxiety [10].
	Website links to simple written explanations, e.g. BBC Bitesize.	Simple explanations in an alternative format [10].
	Website links to "When will I use [topic] in real life?" pages.	Engages students on non-mathematical degree tracks and demonstrate potential applications to reduce maths anxiety [10, 61].
	Formative, untimed, unassessed quizzes, repeatable with parameter randomisation, created in Numbas.	Increases student self-efficacy, motivation [7, 56], reducing maths anxiety. Time to make sense of questions and reflect [67]. Reduces anxiety through desensitisation and practice [10, 47].
	Anonymous Padlet (virtual bulletin board) for students to ask questions while going through materials.	Allows students to ask any questions they needed without the pressure of asking in front of their peers [61]. Explicit encouragement of students to ask "silly" or "obvious" questions [10]. Reduces maths anxiety [67].
Large-group interactive sessions	At the start of the session, the tutor displayed the anonymous Padlet questions and discussed the answers.	All students benefit from the explanations at the beginning of the lesson. Students feel more prepared to try some problems. Reassurance that other students had the same questions.
	Anonymous, whole-class multiple-choice quiz. Incorrect answers were designed to reflect common mistakes and misconceptions [10]. When in-person, this was done with Plickers where students did not need their own technology; online, this was done with Kahoot!	Quiz conducted anonymously with competition elements such as scores and leader boards turned off to reduce maths anxiety [10, 65]. Quizzes provide an element of fun to reduce anxiety [61]. Allows students to test their knowledge in a low-stakes environment and get immediate feedback on their understanding [42].
	A distribution graph of how many students chose which options in the quizzes.	Allows the tutor to determine how many students got the correct answer, and how many made the common mistakes for that topic. Informs the required level of detail of explanation when the tutor goes through model answers on the board [42].
Smaller-group tutorials	Worksheets of exam-style questions, worked through within the tutorial time individually or in small groups.	Experience of exam-style questions [10]. Groupwork reduces maths anxiety [64], but since some students prefer to work alone, the choice was offered.
	The tutor helped when asked or if students looked like they needed it but didn't want to ask.	Asking questions in smaller groups reduces the social stigma of asking questions and reduces maths anxiety [61].
	Worked answers were put on the VLE at the end of the week.	Students can check their own answers at home in a low-pressure environment and find out where they went wrong [10].
	A small number of groups chose to use a short amount of time at the end of the tutorial to work through solutions together on the board.	Allowed students to work together to cross-check their answers with other and discuss problems in a collaborative, friendly environment [46].

participants were from the full range of disciplines offered at the university, including social science ($n = 15$), arts and humanities ($n = 9$), the sciences ($n = 7$), and medicine, dentistry and health ($n = 3$), with 31 studying full-time and 3 studying part-time. All participants were undergraduates, and were mostly distributed across first, second, and third years of undergraduate study; the exceptions to this were the six students in the 2020–21 cohort who had completed their course and left the foundation department, but due to the interviews taking place over the summer of 2021, had not officially started their first year of undergraduate study. Participants were from the full range of age brackets in the department (22–25 through to 61–70), and there were representatives from every year of the flipped learning initiative. Additionally, participants' final results for the Maths and Statistics module were across a range of grade boundaries. A full demographics table is available in Appendix A.

2.4. Data generation

The data for the study was generated from individual semi-structured interviews with the tutor. The interviews were conducted in two rounds: round one was in early 2020 before the COVID-19 lockdown and invited participants from the 2016–2019 cohorts; round two was in the summer of 2021, inviting participants from the 2019–2021 cohorts. The interviews were held in two rounds so that students who were in the 2016–17 cohort (who had finished their maths module in June 2017) were interviewed a maximum of two and a half years after finishing the module. This was done to try and capture students' experience before their memory had degraded too much. However, it is recognised that the time between finishing the course and being interviewed is still fairly long, and therefore there is likely some memory bias. Attempts were made to account for this by providing a reminder of the structure of the flipped learning course in the interview invitation, and at the start of the interview itself. The reminder took the form of an A3 document detailing the three parts of the flipped structure (online materials, large-group session, and smaller-group tutorial), including details and pictures or screenshots for each type of activity carried out in each session. Students were also able to access the module on the virtual learning environment as access was not revoked after they had completed it, and during the interviews, several participants mentioned that they had done exactly that to remind themselves.

The round one interviews were held in private meeting rooms in the university and audio recorded using a dictaphone; towards the end of round one interviews, the COVID-19 situation became clearer and for the participants' safety the last four interviews were held on Skype and recorded using the in-built recording function. The round two interviews were held over Google Meet and recorded with Echo360 screen capture software. Otter software was also used to automatically generate a transcript to speed up the transcription process. The duration of each interview was approximately 30 min, with a minimum time of 23 min and a maximum time of 1 hour and 2 min, although the longer interview included a lot of unrelated chat which was subsequently removed from the transcript. Both transcripts and recordings were kept on a password-protected laptop until the completion of the project.

At the beginning of each interview, participants were asked to sign a consent form. They were reminded of the purpose of the study and that the interview was only about the mathematics portion of the course, not the statistics (which had been taught differently). They were also informed that the interviewer was seeking honest opinions and they should think about negatives as well as positives when answering to mitigate potential bias from the interviewer being the tutor. Finally, they were given a short reminder explanation of the structure of the flipped course before the interview commenced.

2.5. Instrument

The interview protocol is included in Appendix B. Broadly, it covered: whether students enjoyed the method; how it compared to traditional teaching or other flipped learning they'd had; the challenges and benefits of the method; support; moving online (in round two interviews only); whether students would enrol in another flipped class; and questions about the specific technologies used. Students were also given the opportunity to talk about anything else they wanted to add or thought it would be helpful for the interviewer to know. The interview protocol was piloted using colleagues to check questions for clarity, sense, and appropriate order. As a result of piloting, the protocol was adjusted to re-order some questions and to clarify others.

2.6. Data analysis

The data was analysed using inductive, reflexive thematic analysis where codes and themes were generated from the data without an existing coding framework [12]. Thematic analysis was chosen as it offers the opportunity to inductively find patterns of meaning within the data. This will address the research question by finding what themes underly students' experiences and perspectives of the structure of the supported flipped learning model. It is a theoretically flexible approach that enables the researcher to move beyond any expectations they had for participants' responses as the course designer and educator, in order to identify and represent students' perspectives as understood by the researcher. In this way, the analysis is consistent with constructivist aims.

The analysis used Braun and Clarke's [12] framework for thematic analysis. The framework consists of six phases including familiarisation, coding, theme generation, theme development and review, theme definition, and reporting. Initial familiarisation occurred during data generation. The Otter transcriptions from the interviews were then reviewed alongside the recordings and edited for correctness and to add the speaker identification, resulting in verbatim transcriptions, anonymised with pseudonyms. The anonymised transcriptions are available in the associated dataset ([71]). The transcriptions were then read immersively with no specific focus. Coding, with both semantic and latent codes, was carried out on the transcriptions, and these were grouped into meaningful candidate themes generated by the researcher. These candidate themes were then reviewed at the extract level and developed further, being considered in relation to the whole dataset. This was followed by further refining and defining the themes until they were judged by the researcher to represent a thorough understanding of the study. The themes were then named according to the content of each theme and the coded extracts. This was a highly iterative process, requiring much development and review.

3. Results and discussion

This paper will focus on the overarching theme of structure, and report on six themes within that. It will address the research question that asks about students' perspectives and experiences of the structure of the supported flipped learning model. 17 of the 34 students expressed that they had experienced maths anxiety before or during the module, confirming that it is a common problem amongst foundation-year undergraduates.

3.1. Timing is important

This theme refers to students' feelings that the timing of learning activities in the flipped learning was important, both for the overall structure flow, and within the structure of each lesson.

Throughout the interviews, students felt that the supported flipped learning model added structure, which helped them to engage regularly and structure their learning:

> Sophie: I think that it's like quite a structured method, in that releasing the material, go into the [interactive session], go into the tutorial, I don't think there's a lot that could probably go wrong with it. But I think it does help.

As shown in this extract, there was a feeling of safety from having such a structured method, with Sophie saying, "I don't think there's a lot that could probably go wrong with it". This enables a safe-feeling environment where students can focus on the mathematics itself rather than the structure of the course. Students also expressed that the structure of the course was predictable as it remained the same across the year, and that they appreciated this fact. This is in agreement with Ramirez et al. [47] who found that consistency in format and structure reduced students' cognitive load and therefore their anxiety. Consistency within the lessons themselves was also appreciated:

> Michelle: it got into a rhythm of like, "Oh let's look at the funny Kahoot names", "Let's see that", you know, it did get into like, there was almost a rhythm of our [interactive sessions]

It was evident across every interview that students felt that having the flipped materials in advance was a big benefit as it increased their ability to prepare and to identify their strengths and weaknesses for each topic before coming into class, which helped to reduce their maths anxiety:

> Poppy: I could access it prior to the [interactive session] so I knew what I was coming into […] and then that kind of helped me with focus but also if I needed to ask a question, or I kind of knew which bits I might need to ask you about, or I might need to work on. […] Or if there's something I was just a little bit unsure of, if it came up on the Padlet, I was like, "All right now so I did that and that was alright".

This allowed students to self-regulate their work and increase their own autonomy in what they were learning and focusing on, which is in agreement with other authors [2, 39, 58]. Being able to identify the parts of the topic that they felt they were weakest on meant that students felt that they could receive more individualised help [6], as shown in the extract above. This also means that educators can answer a question that a student has prepared in advance, rather than having to guide the student while they think of exactly what their question is, resulting in a more efficient use of time [4].

The 'supportive' interactive session was considered an important part of the perceived success of the model:

> Grace: if you'd give me the materials and then give me the quiz, without the bits in the middle, and the [interactive session] that we did where we went over things and it were explained, without that step, I don't think you'd have got to end step.

Students felt that the progression in difficulty between the interactive session (Q&A followed by multiple choice questions) and the tutorial (short-answer exam-style questions) allowed them to take a middle step instead of jumping between initial content learning and difficult questions. Grace's quote above implies that she felt anxious about moving between these steps, and that the supported model mitigated that. The interactive session meant that students felt they could fill in the gaps in their knowledge that they had identified in the flipped materials, and that having multiple opportunities for problem solving at different levels is a major benefit of flipped learning [15], and therefore more so for the supported flipped model. It was also suggested that the interactive session helped everyone to be on the same page before moving on, acting as revision for students who were comfortable with the material and assisting those who were struggling. This interactive session therefore reduces the effect where students with lower levels of self-regulation can struggle with flipped [27, 40, 45], enabling a more structured learning experience that is flexible enough to allow all students to benefit.

The time between the interactive session and the subsequent tutorial was also discussed by many students, but with inconclusive results. Some of the students liked having their tutorial immediately after the interactive session, whereas others like having time to absorb what they had just learned before moving on:

William: I was lucky as the tutorial was right after my lesson, and so if there was a problem and I hadn't had chance to do that, then I still felt I was keeping up.

Adam: I got lucky with the fact that I had my […] tutorial the day after, and I know that my learning technique is about reinforcement, is about revisiting it.

The expression of luck in both extracts is notable, as students were assigned to a tutorial group that fit their timetable as they were all doing different modules due to being on a range of degree tracks, and this could be perceived as random allocation by the student. Future development of the model could involve assigning students to their preferred tutorial time, although student numbers would perhaps be less manageable this way. This would also increase students' feelings of autonomy [39] and allow them to discover and develop learning strategies that work for them. However, based on the quotes above, it is clear that these students felt that the structure of the course did fit their learning strategies, or that they had developed strategies that worked with the structure. Being able to have awareness of their own feelings about mathematical tasks and use their own strategies helps to reduce maths anxiety [64].

Lastly, some participants expressed wishes that the interactive sessions were run either slower so they had more time to think about each question, or faster as they knew the answer and wanted to move on quickly with less repetition. This is likely an outcome of the mixed-track and mixed-ability cohort, and short of streaming students, it is probably unavoidable and inherent to many classes in higher education.

3.2. Structure of materials

This theme captured how students felt about the way the material was structured, both in the flipped learning materials and the lessons themselves.

A wide range of flipped learning material was provided for students in advance of the lessons. The availability and large amount of material provided was seen as a positive, with students taking ownership of their own learning to use the material in a self-regulated way that they found useful:

Deborah: And then if I got stuck on anything, I'd like scroll down to that, you know whatever I've got stuck on, and just work through the videos and just see which, like I said, sometimes it's like "Oh yeah I've got it straight away" and others, like, "Don't know, next one, lost on that, try another one". [laugh]

Doug: If I felt I really did understand it, I would go straight to the quizzes.

As these extracts demonstrate, students tended to access the written materials for initial learning before moving to the videos and quizzes. Sahin et al. [51] suggested that for mathematics education, reading may not be as effective as videos, so it is interesting that students tended towards reading first. This may also reflect the order in which the materials were presented, where the slides with written explanations were the first on the list. The choice of which resources to use and in what order, where students were encouraged to do what worked for them and what they felt they needed, increases student self-regulation of their work [58] and may increase engagement [6] due to a greater amount of choice than in traditional learning.

This wide range and amount of material and support also helped to reduce students' maths anxiety:

Deborah: If you can't do it, you know, there's you, there's [maths help centre], there's, you know, all the extra videos and worksheets and things like that so it was like, it just kind of turned a scary subject into something that it was like you know what, if I can't do it, I'll be able to because there's something that's available to help me. It made it a lot less scary.

Participants felt that the amount of material, followed by consolidation opportunities in both the interactive session and smaller-group tutorial, provided students with lots of practice:

Amy: it's like, switching it up a bit. So, really, you've got like three different ways of practising one topic or whatever.

Low-stakes practice or repetition is considered part of success in maths, not only to reduce students' maths anxiety [56] but to increase student achievement and understanding, with repetition with variation providing the best results [35]. The structure of the supported flipped model provides repetition with variation, and it is shown by the extract that students appreciate this, although the effect may also be shared with students experiencing an active-learning classroom [19].

Students also commented on the ability to look back at older material and have it all located in one place, and how they found this useful:

Sam: everything was well structured. Everything's individually like filed. You knew where to find- they were well, like, titled as well. You would find that material. It's easy to go back and things if I needed them.

The flexibility of the approach was also viewed as important by students:

Linda: you'd go through the question afterwards. Whereas if everyone got it right, move on to the next, didn't need to. […] you could tailor it to give us more questions on the areas because, and you notice in [the interactive session], there was a few and you got the hang of this now […] move onto the next bit

This was particularly noticeable in the supported flipped model structure, as the interactive session was designed so that the tutor could move between topics as required by the students in a responsive way, as indicated by the extract (Linda). This adaptability is important for flipped learning classrooms [7]. Further, the use of different topics and different delivery methods was appreciated by students and helped to reduce their maths anxiety:

Hilary: I enjoyed the variety of different things. Yeah. And again, it makes you think about maths in a different way to the traditional way, which for me at school, a long time ago was terrifying.

The extract above shows that Hilary moved from viewing traditional ways of learning maths as scary to a sense of enjoyment due to the different and flexible approaches used in the supported flipped model. There was also recognition that having this responsive approach allowed the flipped learning to work for large class sizes, although the following smaller-group tutorial is important to allow for more targeted one-to-one support, as per Bhagat et al. [6].

3.3. Online enables access

The use of online learning is a crucial part of many flipped models, particular the supported flipped model presented in this study, where the learning materials are introduced to students in an online format. Online learning further gained importance during the COVID-19 pandemic which impacted the 2019/20 and 2020/21 participants due to a switch to being fully online, including the interactive session and smaller-group tutorials.

This theme explores the participants' ideas that online learning is better than offline learning in terms of access, and that the infrastructure behind a flipped learning model is important for students. Infrastructure is one of the primary components of course structure [29].

Participants commented that online learning allows distance learners to contribute, which may mean students who are stuck in their home countries due to COVID-19:

> Georgina: they just ended up doing the whole year from Hong Kong or from Singapore or from China. Yeah, we've got somebody who regales us with tales of his long lunches in France. He lives in Provence. And he says, "Oh, I had a lovely duck for lunch today". [laugh] And we're all sitting here eating Gregg's. [laugh]

But it also may mean students who commute into the university:

> Adam: I live a 25-minute drive from [city], so to commute in for what was, or what would have been, a lecture or a seminar may have seemed like a waste of valuable time where I could just crack on with the maths.

Commuting into university, rather than living in the city, is common for widening participation students [13, 60]. Therefore, reducing or eliminating commuting time was viewed very positively by the participants as the time could be better spent on their studies, as well as reducing the effort required to engage with the learning. This may increase engagement and motivation to participate [6, 48].

The concept of time was evident throughout the interviews. How the structure of online working enables time flexibility was viewed as particularly important for students who have children, jobs, or other life-focused responsibilities:

> Bel: I could say, "Right, we'll do swimming, we eat, I'm going to sleep" so I could sleep at six. And everybody goes to bed at seven. And then when everybody's asleep then I wake up because it's quiet. And then I work on.

Being able to engage with the majority of the work when she wanted was an important part of satisfaction with the supported flipped learning model, and demonstrates that students will self-regulate as required, and flipped learning can help them do so, in agreement with Sun et al. [58].

Participants also felt that having online learning reduced the maths anxiety that they would have had were they trying to keep up in a traditional in-person learning setting, which is in keeping with Thompson et al. [61]:

> Veronica: I think it worked well because it was online, it made it really accessible. I don't see that it needed to be in a classroom, if anything that might add to anxiety, particularly if people are sat there going "Oh I don't want everyone else to look at me when I'm asking that question". I feel like it made people actually ask questions instead of just sitting in silence and not knowing the answer. I definitely know that's what I would have been like, particularly the first few weeks I wouldn't have said anything because I didn't want anyone to think I was stupid, or not smart enough to be there and I think that's the good thing about online work because you could be faceless, you could ask a question. People would see your name, but they wouldn't remember who asked the question, they'll just be grateful that someone asked that question.

Having the flipped learning materials online also gave participants the opportunity to pace themselves and structure their learning in a way that worked for them:

> Deborah: I think if that had been classroom based, I don't think I would have got it. I think I'd have felt too rushed […] I don't think I would have had the time or, just to sort of work through it at my own pace in my own way.

> Clara: I could do it in my own time you know I just kind of have a look online at what was in the maths thing. And you have to sit at home and google it, do it with a cup of tea, and yeah not have the pressure, I guess.

The ability to self-pace is again in agreement with autonomy and self-regulation principles from the literature [39, 58], and as shown from the extract, actually increase student engagement and motivation over a traditional classroom experience [6, 48]. As shown in Clara's extract, students also felt that being able to self-pace meant there was less pressure, it was more comfortable for them. Clara revealed in the interview that she had maths anxiety in certain situations, such as getting help or learning from unfamiliar sources, and so this ability to approach maths in a low-pressure and familiar way was crucial for a reduction in her maths anxiety.

Although online learning was a way of life during COVID-19, many higher education institutions are returning to in-person teaching. Although the benefits of online lessons may be lost in the future, in the supported flipped model, the flipped learning part remains online. This enables students to continue taking the time they need to work through at their own pace and at a time that is convenient to them, and this has been shown as a structural aspect of a higher education course that is particularly important for students.

3.4. Distractions online and at home

This theme encompasses the idea of distractions. Due to the nature of flipped learning being a primarily self-directed learning approach, it is important to consider how distractions are inherent in the structure more or less than traditional learning, and whether they can be mitigated.

There were two opposing viewpoints in this theme. The first was students who felt that online working reduced distractions:

> Robert: I think [online] was probably a little less distracting. […] it was only ever distracting, in person, bad enough once where I had to leave because I panicked, but definitely you know doing it in my own bedroom, you know, it was less distracting with everybody about so I'd say that was one of the benefits definitely.

And those who felt that online working increased distractions:

> Charlie: when I'm in my home environment, the same room that I play my games, that I do my job […] and that I study, it's very hard for me to focus on a video [laugh] or people talking, like without me getting distracted. "They're talking to me about this but I can easily just press this tab here and look at Reddit whilst they're talking" and then I'm looking. [laugh]

Throughout the interviews, more students felt that online working reduced distractions rather than increasing them, although this will vary depending on individual student differences and preferences. Online working specifically reduced Robert's social anxiety, and potentially therefore his maths anxiety, and therefore there may be opportunities for online and flipped learning to cater to students with disabilities or other learning differences.

The extract above makes it clear that there is an overlap between online working and working from home. Another student felt that working from home specifically was distracting:

> Henry: it's very easy to forget, and you're sort of doing something else you and you think, and then it slowly kicks in, "Oh my god, I'm supposed to be in a maths tutorial".

For many students, working online means working from home, however this does not necessarily have to be the case post-pandemic. When university buildings and libraries are open, students will be able to locate computers or private study rooms to do their online work whilst on campus, although this will require the maintenance of good infrastructure. Frequent student input in live online sessions can be encouraged to avoid drifting towards distractions; for offline activities such as pre-lesson learning in flipped classrooms, expectations are set that students cover the material before class, and this puts the onus and ownership on them to find ways to reduce their own distractibility. Students can also be encouraged and supported to use online calendars and set up alerts for upcoming classes if necessary to avoid forgetting about them.

Distractions are inherent to any learning environment. While the larger amount of self-directed study in the structure of flipped learning compared to traditional teaching may cause students to feel they are sometimes distracted, it can also prompt students to create strategies to manage their own attention. Traditional learning in higher education, particularly lecture-based learning, is also rife with distraction for students [22, 43]; it may be that the structure of a flipped learning or other active learning environment would actually reduce these distractions.

3.5. Finding online difficult

In addition to the distractions theme, this theme explores the views of students who have expressed finding online learning difficult. This may be a temporary effect of the pivot to online due to the COVID-19 pandemic rather than a structural aspect of the supported flipped model. However, there are expectations for students to access and engage with the flipped materials online.

The first difficulty students had with being online was problems with technology due to their own technological literacy:

> Rebecca: The online learning has been quite tricky. It started off as very tricky, because I was making errors in, you know, finding the microphone. Now I know that the telephone button is to actually cancel the lesson, you know the room, the class, but after I gave my answer in an English lesson, just as the tutor was speaking, I thought I was turning my microphone off and I turned the, you know, to come out of the class, and then I panicked and I nearly started crying and I was so- I felt like a failure, do you know what I mean?

This extract shows that students who are not confident or familiar with technology struggled to use online learning for classes. However, it is worth noting that Rebecca suggested that she felt she had improved hugely over the year, and was quite confident in attending our online interview. The first year of her learning was done primarily in-person, and she felt that accessing the online flipped learning materials was fine, it was just having online lessons that she struggled with.

Participants also stated that they felt anxious and under pressure having to attend online lessons:

> Oliver: I found it harder to bring up my questions or find the right moment to bring up a question. Whereas in person, you have a lot of those body language cues and things like that to let you know when the appropriate time to speak up is, and it just felt like I didn't get a lot of opportunities to do that with the online bit.

This indicates that there are different social pressures for lessons that are being held online, and that adapting to a different way of communicating was difficult for many students. This may be linked to the fear of asking questions in front of others that has previously been found in the literature [61]. The supported flipped model included the option to put questions on the Padlet before the live classes in an attempt to mitigate this effect, which was considered effective by students:

> Ethel: I think maybe the Padlet, you know the asking the questions up front, I think that is more conducive to getting into a conversation with somebody about the material beforehand.

Related to students' own technological literacy is problems with the technology itself, or the lack of the appropriate technology:

> Clara: we have done some things this year where people do it on their phone, you know with like Kahoot and things like that but actually sometimes that doesn't always work because firstly you have to assume that you've got your phone and then the it's got enough battery. And that also the other thing is that it can time out.

> Ivy: because everything was online, I live in the middle of nowhere, and my internet- if it rains, my internet will go out, if there's a bit of wind, it will go out.

Unreliable technology has long been a common complaint in the adoption of technology for education [26, 52]. Giving students extended time to engage with online learning materials, such as advocated in this supported flipped model, may help to mitigate these problems.

A small number of students stated that the lessons being online during the pandemic reduced their motivation to engage with them:

> Hinata: I think the fact that it was online probably reduced, with the live [interactive sessions], it reduced my engagement, but I was still engaging with the material that was being posted, but the actual live [interactive sessions], I think I fell asleep during some of them. I'll be very honest. [laugh] […] It wasn't as mentally stimulating as being in a classroom where there's a group of people kind of just working through the same thing

It is interesting that the online flipped materials did not have the same effect as the online lessons, with all the students specifically stating that they were engaged with the flipped materials. It is clear that students felt that the classroom camaraderie was a major part in engaging them in lessons. This is in agreement with Trust et al. [63] who found that flipped learning increase student collaboration. The important of camaraderie is further borne out by the following extract:

> Georgina: Learning in lockdown online it's really isolating because you have fuck all to do outside of class because you were in lockdown. You had your one hour a day of mandated exercise by Boris [the UK prime minister during the pandemic], everything was shut and it was depressing. Online learning without lockdown is almost as social as in person learning. […] lockdown learning is not flipped learning or blended learning

Clearly, Georgina felt that the lockdown was the main reason behind the feeling of isolation, rather than online learning specifically. Both Georgina and Hinata were part of the 2019/20 cohort where lockdown began three quarters of the way through their academic year, and this could have had a dramatic effect on their motivation. In fact, no students outside the 2019/20 cohort expressed lower motivation or engagement with online work, which may support this. In fact, many students commented on the fact that the supported flipped learning model specifically is easily moved online, and that this was beneficial in case of unexpected events that required not attending in-person classes. Either way, the structure of the flipped learning model itself did not seem to be the cause of students finding online learning difficult.

3.6. Better than traditional teaching methods

This final theme examines students' suggestions that the supported flipped learning model and structure was better than other learning that they had encountered.

Many students found the supported flipped model easier than traditional methods of learning:

> Kate: [Flipped] is way easier. You can really sort your time out with this […] having it all there and all the different, like, resources, you could pick and choose what you wanted to do, it's much more helpful this way. Much more helpful.

As shown in the extract above, this was often due to students having time flexibility and being able to take ownership over their own learning, and other participants suggested it was helpful as it fit their learning preferences and reduced their maths anxiety. This is in agreement with the literature that suggests flipped increase student autonomy and self-regulation [39, 58], and that it reduces maths anxiety ([70]). Very few challenges were identified about the structure of the supported flipped model, and these were primarily about timing and technology, as described in the themes above. Students' preference for the supported flipped model was also based on the high levels of interactivity in the classroom sessions:

> Doug: I prefer the flipped- your style of flipped than the traditional lectures, mainly because of the, I'll go back to the interaction. You're having to positively do something. Because you soon get caught out if you've not done it.

Georgina described traditional teaching models with lectures as "anachronistic". Perhaps other learning models with high levels of interactivity would also be as successful as the supported flipped model from a student perspective, but it is certainly clear that once students encountered a more student-centred active-learning environment, traditional teaching is no longer as appreciated:

> Henry: So, at the end of the day, flipped learning I think works. It's one of these things that where, if you've never done it you don't realise how good it is. When you have done it, you never want to go back, to be honest. [laugh]

This is also in line with the literature, where students were found to find flipped or other active-learning experiences more interesting and enjoyable than traditional lectures [6, 19]. It is also supported by Kim et al. [27] who found that flipped learning courses had higher levels of student course satisfaction.

4. Limitations and future work

This study was conducted in one Russell Group institution in the north of England. However, since the supported flipped model was viewed positively across all five cohort years interviewed, and anecdotally, others have tried it successfully on a smaller scale, there is evidence to suggest that it may be successful on a wider scale than the one mathematics module explained here. There is no evidence to suggest it may not be successful in other institutions. The participants were highly varied in age, gender, mode of study, and were on a variety of degree tracks including those outside the science and maths route. The participants, therefore, offered diverse perspectives and therefore the convergence into coherent themes reflects the success of the supported flipped learning model. It would be interesting to explore the use of this model in other disciplines. Overall, students seemed to think that the flipped learning model successfully reduced their anxiety surrounding mathematics, although the evidence was often indirect as it arose through conversation within the interview and was not formally collected.

Students were unanimously positive about the supported flipped learning model, but there were suggestions as to potential improvements in session timing, technology problems, and greater community generation for online working. Future work could include focus groups to enable students to participate in the development of the model to attempt to address these issues and any others.

The students who volunteered to be interviewed were likely to be the ones with positive opinions of the flipped model. However, anecdotally, anonymous module evaluations showed that all but one or two students each year were positive about the flipped learning model. The interviews were held by the tutor who delivered the course. This may mean that students were less likely to express negative views. Mitigation of this effect was attempted by explicitly encouraging students to talk about negatives throughout the interviews, and to reassure students that the interviewer did not get offended. The interviews themselves were not all positive throughout, with participants clearly attempting to think of challenges they encountered in their learning, which does indicate that perhaps the assumption that these students would only respond positively is not true. Another limitation is that for some participants, the interviews were conducted two or more years after their maths module ended, and therefore there may be some memory bias. Mitigations were put into effect by offering multiple reminders of the structure and activities in the flipped learning model, as well as allowing students access to the module on the virtual learning environment.

Participants' final results for the module were across a range of grade boundaries, and several students self-identified as struggling with maths. It is particularly important to include these participants as it is often these struggling students who encounter particular challenges with flipped learning. However, as shown by this study, even students who struggle with the mathematical content are positive about their flipped learning experience and felt it helped reduce their maths anxiety.

A further implication for future research is the disentangling of online learning and lockdown learning. As evidenced by the themes and extracts discussed here, these were unavoidably intermingled for the students during the 2019/20 and 2020/21 academic years due to the COVID-19 pandemic. Even where lockdown was not active, there were severe restrictions in place that prevented students from engaging at university in a 'normal' fashion. It would be interesting to explore how online classes are received when there is no pandemic.

5. Conclusion

This study describes a new supported flipped learning model based on maths anxiety reduction principles. A good course structure is important for effective flipped learning, both in terms of the educational objectives and infrastructure [7, 29], and to this end, this study asked what are students' perspectives and experiences of the structure of this supported flipped learning model?

It was found that participants believe that the flipped learning model presented here is superior to traditional teaching methods. The structure of this model gives students a sense of progression while providing a safety net for students with lower levels of self-regulation who are often challenged in flipped environments [27, 40, 45]. This model can help to increase autonomy and self-regulation strategies in all students. The structure of the supported flipped model also specifically reduces mathematics anxiety which is important for cohorts where maths anxiety may be high such as foundation students or students on non-STEM degrees doing mathematics or statistics.

Lo [30] asks how flipped learning can continue in a fully online environment; this study has shown that in order to successfully pivot to online learning, having the appropriate structure and infrastructure is important. The supported flipped learning mode presented in this paper has the ability to move almost seamlessly between in-person and online teaching, which is of importance in our uncertain modern world. Additionally, this supported flipped learning structure makes use of a range of learning technologies and computer systems which are supported by maths anxiety reduction principles, and therefore educators should consider this when designing flipped learning environments, whether that is just using VLEs or being fully online. Videos are one aspect of flipped learning, and the design of these is important [7], but flipped learning needs to move beyond simply videos to a fully-realised model of integrated parts. This model offers that.

The following implications for practice are suggested for educators who wish to use or are already using flipped learning:

- Ensure consistency in the structure of the flipped model.
- Give a wide range and good amount of learning material, with varied repetition. Beware of the amount becoming overwhelming; if necessary, ensure students know they can choose which parts to use.
- Allow students plenty of time to engage with the flipped learning materials so they can pace themselves and take ownership over their learning.
- Include low-stakes practice for all subjects. Follow maths anxiety reduction principles for mathematics education.
- Incorporate a supportive step between the learning materials and problem-solving activities. The allows an easier transition and acts as a safety net for students who may otherwise fall behind.
- Include interactive activities.
- Consider how much online learning would make sense for your cohort, and which stages of the flipped classroom can be done online. This can be particularly useful for widening participation or commuter students.
- Find ways to foster camaraderie and friendliness in the classroom to reduce anxiety and encourage peer support and collaboration.

Additionally, there are several implications for theory from this study:

- Flipped learning can be successfully implemented in a fully online environment.
- The maths anxiety reduction suggestions from the literature seem to reduce students' levels of maths anxiety.
- Flexibility of approaches seems to reduce maths anxiety and lead to a positive flipped learning experience.
- Lessons from lockdown learning should be disentangled from online learning going forward.

Overall, this study advances current use of flipped learning by incorporating a supportive step and suggesting new structures and uses of technology to reduce anxiety. Students feel that this model delivers on the structure of the timing of lessons, the structure of material used, and the infrastructure of delivery. It is clear that participants from a range of disciplines are very positive about the supported flipped learning model for foundation mathematics, particularly for non-STEM courses. This flipped model is therefore a useful tool for both mathematics educators and educators from other disciplines. Due to the success of its use during the COVID-19 pandemic, this model could also be of use to educators who are considering how to capitalise on the increase in online learning and use of technology in their HE courses.

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Supplementary materials

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