The Flipped Classroom

A Teaching Enhancement Fund Report

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Executive Summary

The “flipped classroom” refers to a strategy of blended learning in which “homework” precedes class time. This approach started in University programmes (graduate and undergraduate) but was only called “flipping” in 2007 in a College programme (Bergmann and Sams, 2012). From this point it has grown in popularity and has attracted much attention recently, particularly in STEM (Science, Technology, Engineering and Mathematics) education.

The central driver for the flipped approach is the dissatisfaction with levels of conceptual understanding achieved through traditional methods. The recent impetus derives also from the ready availability of video technology and classroom response systems (“clickers”), which affords the opportunity to replace lectures by video recordings and lecture time by interactive classes. In this approach students come to classes having done the required preparation and lecture time can be spent on more challenging aspects of learning. Although the pedagogy does not require the use of video for the pre-class delivery of material, and most of our local examples will eschew this mode, much of the activity and the pedagogic research, has been around the use of video.

This report is based on a project carried out for the University with funding from the Teaching Enhancement Fund to explore the use of flipped learning at Leicester. We aimed to observe and report on a range of non-traditional approaches that can be considered to come under the general heading of flipped learning and to record the experiences of staff and students experimenting with the format. Lecturers volunteering to participate in the project came mainly from STEM disciplines.

We find that there are significant challenges to making flipped learning work, to address which we can be guided by some of the experiences at other institutions, which we report, and by the research literature. Challenges include student engagement with pre-class preparation, attendance at classes when lecture material is available on line and, above all, the generation of suitable in-class activities. We provide some guidelines for staff wishing to implement the flipped approach. Lecturers who have taken up the challenge have done so in the belief that this is not a passing fad, but a genuine revolution in matching pedagogy to technology for the 21st century University.
1. Overview: The Flap about Flip

If there is no problem to fix, perhaps we should not worry about fixing it. However, a lot of research shows that much of what is done in higher education is not particularly effective (Weinman, 2014) so perhaps there is a problem. Let’s start with the traditional lecture.

Walter Lewin’s lectures are available on the web. To quote from the blog ‘Pseudoteaching’:

His demonstrations were thrilling. His board work was impeccable . . . . It looks like good teaching, but he was the one doing all the talking. It looks like the students are learning, but they were just sitting there watching. To judge by the failure and drop-out rates, and considering that traditional teaching does not get much better, it did not work that well.

As a result the Massachusetts Institute of Technology (MIT) has abandoned lectures in introductory physics courses and replaced them with small group interactive instruction.

Closer to home, David Sands from the University of Hull tells a story in which he tested his students’ retention after a lecture by repeatedly telling them that he was giving them one important message, and that if they took away nothing else, that message at least they should remember. He tested them at the end: of course, they all remembered that there was something important they had to remember, but Sands claims that not one of them could remember what it was. In another test that one of my colleagues conducted here at Leicester, he compared students’ lecture notes to what he had said and had written on the board in the course of the lecture: as he put it looking at the results: “with these notes no wonder they don’t answer the examination questions correctly!” So it’s not just Harvard students who do not shine.

Much work has been done on techniques to improve the lecture. We now accept that students cannot absorb new content continuously for an hour, so there should be breaks; we may hand out lecture notes to subvert the need to listen and write at the same time; we provide PowerPoint slides for study after the lecture or even full video recordings; we use interactive devices of various types to encourage audience participation. And it all works fine – for a single lecture, or perhaps two. As we have seen from the research, it does not work well for a course of lectures (e.g. Freeman et al., 2014). We may not know that anything else will work any better, but we can explore the possibilities.

It has always been the case that students who come prepared get the most out of a class; the issue is how this can be achieved. In the Humanities the answer sometimes seems obvious: read the book. But this is easier said than done at anything other than a superficial level. The uninitiated (all of us outside our specialisms) need a guide. So we read the book about reading the book (the handy “Short Introduction to...”) and to make it even more accessible, we invent the lecture. Thus, the order of things is inverted: come to the lecture (unprepared) and then read the book. Hopefully one comes to the next lecture a little bit better prepared for the next intellectual challenge.

In STEM subjects, particularly the more mathematical ones, the structure has evolved so that the lecture notes are presumed to contain all the required information and students are then invited to test their understanding on some set homework exercises. The problem is that much lecture time is

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then taken up with the lower levels of thinking (knowing and understanding in the learning taxonomy introduced by Bloom et al. (1956)) leaving little time to develop the higher levels (analysis, evaluation and synthesis) which students are supposed to pick up from the exercises. The basic concept of flipped learning is to use the homework time for the lower levels and to redeploy the lecture time for class discussion and practice at higher level thinking. The technology that makes this widely implementable is the computer video in which the lower level facts and concepts can be presented in accessible (lecture!) form (Bergmann and Sams, 2012).

In pure flipping, the live lecture is replaced by a virtual lecture leaving the lecture time free for interactions between the lecturer and the – now informed – students. Most lecturers find pretty soon that students do not really like to watch an unedited recording of a live lecture, for whatever reason, and provide shorter edited snippets to be studied prior to the class time (Enfield, 2013; Mason et al., 2013). We have defined “pure” flipping here to involve specifically video content. Of course, pre-class activities could involve audio or print media, but it has been the access to readily produced video that has underpinned the excitement around the flip movement.

The concept of flipping is based on accumulated knowledge about how students learn. Any one sentence summary of the vast body of educational literature on cognition is likely to sound naïve; but here goes: students learn by doing structured sequences of tasks, adopting a variety of learning styles with multiple opportunities to adapt to feedback and to find relationships between concepts. (In other words, students should act and reflect, read, write, talk, listen, negotiate, build and so on.) The reader may recognise “doing” from experiential learning (Dewey, 1938), “structured” from “constructionist” and “relationships” from “accommodation and assimilation” (Piaget, 1950), “staged” from “proximal development” (Vygotsky, 1978) and “learning styles” from Kolb (1984) and other later authors, but used here in the sense of Waring and Evans (2015) as spelled out in the parenthesis above.

Our one sentence focus on cognition makes education seem very dry, unexciting and functional. Critics will point out that there is much more to learning than that. We should consider also affective aspects (motivation and values, for example) and, some would add, the psychomotor domain (perception and motor skills). Bloom et al. (1956) write a lot about this, but they are hardly ever referred to in the literature, showing how the focus on cognition in learning still has the priority. With this focus on cognition there is this danger that resources are prepared to cater for that alone without understanding the importance of affective aspects of learning. Goals and values are indeed crucial in motivating students and motivation is indeed critical to learning (Ambrose et al, 2010), but these are not issues specific to flipped learning. . The flipped classroom seeks to achieve this by providing a forum for the social construction of understanding.

In terms of implementing the theory there are many principles of best practice in the literature. How does the flipped classroom match the established principles of good teaching? Here we look at two (both of which happen to have seven points). Our opinions are presented in tabular form (tables 1 and 2 below).

Both of these evaluations show how flipping can be used to support good practice. As several staff interviewed for this report, and the research literature emphasise, it is not an automatic formula for success! In section 5 we offer some guidance to successful flipping, based on our observations.
The evidence for statistically significant increases in test scores using flip is weak (see Bormann, 2014 p29). On the other hand the qualitative data on improvements in student engagement are significantly positive (Johnson, 2013). It may be that (as with the extensive PBL literature, e.g. Strobel and Barneveld, 2009) future research will reveal few short-term effects of flipping, but improved higher order learning (in the sense of Bloom’s taxonomy) in the long term.

<table>
<thead>
<tr>
<th>Principle</th>
<th>How fulfilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Encourages contacts between students and faculty.</td>
<td>The flipped class can be more interactive than the traditional lecture</td>
</tr>
<tr>
<td>2. Develops reciprocity and cooperation among students.</td>
<td>Group discussions</td>
</tr>
<tr>
<td>3. Uses active learning techniques. (a.k.a. &quot;Encourages active learning&quot;)</td>
<td>Collaborative application of knowledge, feedback and evaluation</td>
</tr>
<tr>
<td>4. Gives prompt feedback.</td>
<td>Immediate feedback on misconceptions in class time</td>
</tr>
<tr>
<td>5. Emphasizes time on task.</td>
<td>Requires preparation for class</td>
</tr>
<tr>
<td>6. Communicates high expectations</td>
<td>Expectations expressed in higher order questioning</td>
</tr>
<tr>
<td>7. Respects diverse talents and ways of learning.</td>
<td>Multiple resources; multiple modes of interaction</td>
</tr>
</tbody>
</table>

Table 1. Seven principles for good practice in undergraduate education (Chickering & Gamson, 1987)

<table>
<thead>
<tr>
<th>Principle</th>
<th>How fulfilled</th>
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<tbody>
<tr>
<td>1. Student’s prior knowledge can help or hinder learning</td>
<td>Students have the opportunity to address gaps in knowledge in preparation for classes</td>
</tr>
<tr>
<td>2. How students organise knowledge influences how they learn and apply what they know</td>
<td>The preparation builds a framework for higher level understanding</td>
</tr>
<tr>
<td>3. Students’ motivation generates, directs, and sustains what they do to learn</td>
<td>Flipped learning is generally found to increase motivation (Bormann, 2014)</td>
</tr>
<tr>
<td>4. To develop mastery, students must acquire component skills, practice integrating them, and know when to apply what they have learned</td>
<td>Flipped lecture checks on component skill and gives the opportunities to assess, apply and discuss previously acquired knowledge</td>
</tr>
<tr>
<td>5. Goal-directed practice coupled with targeted feedback are critical to learning</td>
<td>Flipped class gives immediate feedback on students’ preparation for the task or a challenging problem</td>
</tr>
<tr>
<td>6. Students’ current level of development interacts with the social, emotional, and intellectual climate of the course to impact learning</td>
<td>Cooperative learning is found to increase student learning gains (Felder and Brent, 2007). If the students prepare for the ‘what’ and ‘how’ at home there is more time for poignant questions in the classroom.</td>
</tr>
<tr>
<td>7. To become self-directed learners, students must learn to assess the demands of the task, evaluate their own knowledge and skills, plan their approach, monitor their progress, and adjust their strategies as needed</td>
<td>In traditional structures students often strategise rote learning of examination answers. Integrating flipped learning with authentic, complex assignments can address this; also by self and peer marking and collaborative evaluation and target setting,</td>
</tr>
</tbody>
</table>

Table 2. How Learning Works: Seven Research-Based Principles for Smart Teaching (Ambrose et al., 2010)
2. Variations on the Flipped Approach

The word lecture comes from the Latin “to read”; before the invention of the printing press, books were not readily available, so a teacher would read to his (or possibly but improbably her) students. The giving of lecture notes through lectures, which aim to cover all the required material, in STEM subjects is a relatively recent development. Bringing students to a lecture theatre is an expensive operation and quite pointless if all the information is available in books. So, for much of the history of STEM, students were expected to obtain basic material from books, and lectures were reserved for more advanced material from expert specialists. This is still the case in arts and humanities which may explain why flipping is of less (no?) relevance to our non-STEM colleagues.

In more recent history there have been various initiatives to restore the prior status quo. Here is a selection; they all involve some form of flipping.


This is

1. Instructor poses question based on students' responses to their pre-class reading
2. Students reflect on the question
3. Students commit to an individual answer
4. Instructor reviews student responses
5. Students discuss their thinking and answers with their peers
6. Students then commit again to an individual answer
7. The instructor again reviews responses and decides whether more explanation is needed before moving on to the next concept.

**Team-Based Learning** (Larry Michaelsen, Oklahoma, Management, 1974 - )

This approach is similar to Peer Instruction but puts more emphasis on group work and particularly building teams that (its supporters claim) goes beyond collaborative learning.

The Readiness Assurance Process (RAP) occurs at the beginning of each major instructional unit. The RAP ensures that students are held accountable for completing the pre-class reading and have acquired the foundational knowledge that they will need for the in-class team work that follows. At the first class meeting of a module, a multiple-choice test (15-20 questions) is given. It covers key concepts and important foundational knowledge from the readings. The test is first taken individually and then immediately retaken as a team test using the IF-AT (Immediate Feedback Assessment Technique) “scratch and win” testing cards. At the completion of the team test, teams are encouraged to “appeal” incorrect answers for extra marks..... Following the appeals process the instructor provides a short clarification in the form of a mini-lecture.\(^4\)

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The readiness process takes 1 to 1.5 hours. Groups then undertake one or more significant problems over 3 to 5 class sessions. Practitioners insist that groups should be large (5-7 students) and fixed over a semester to generate team-building (Michaelsen et al., 2009).

*Modeling Instruction* (Hestenes, Arizona, Physics, 1989 - )\(^5\)

The first stage—model development—typically begins with a demonstration and class discussion. This establishes a common understanding of a question to be asked of nature. Then, in small groups, students collaborate in planning and conducting experiments to answer or clarify the question. Students present and justify their conclusions in oral and written form, including the formulation of a model for the phenomena in question and an evaluation of the model by comparison with data. Technical terms and representational tools are introduced by the teacher as they are needed to sharpen models, facilitate modelling activities, and improve the quality of discourse. The teacher ... guides student inquiry and discussion ... with “Socratic” questioning.


From this we see that forms of the flipped classroom have been tried and tested in physics in the US over many years. It is video technology that is new to the party and it is into these established pedagogies that it is integrated.

3. The Project

As background to the challenges involved we report first on two early attempts at flipped learning made by one of the authors.

About 30 years ago one of us came to the conclusion that his lectures on cosmology were not very effective because the whole time was taken by attempts to transmit information, leaving only an hour or two for discussion of past papers. In fact, the discussion aspect was often rather desultory and usually involved just another lecture on the solution to the examination questions. I wanted to have a much more engaged discussion with students in the lecture time, which could only happen if they came prepared. To this end, I made a series of videos – not just videos of the lectures, but, with the help of what was then Audio Visual Services (AVS), some recordings with quite high production values. The videos were each much shorter than the standard lecture slot, and fewer in number, but covered all the relevant information. I thought that these would be much better than my live action versions with all the fluffs and pauses. They were recorded on video tape. Unfortunately, most students did not own a video recorder at that time (before the invention of the web or the DVD) so we had to arrange for them to come in to view the videos at the set lecture times. Strangely, they were of the opinion that I should be present at the viewings, not unreasonably if they had any questions (which was the point of the exercise). And if I was there anyway, why did I not just give the lecture! This was (and still is) an important lesson: just because the technology makes something

possible, it does not mean that it will be pedagogically sound. To emphasise the moral of the story: just because we can put lectures on line does not mean there will be educational gains in doing so.

On the other hand the challenge of teaching mathematics to physics students has been addressed with evident (if not complete) success through the flipped approach, but not without lessons on the way. In 1984 we decided to take the teaching of mathematics for physics in house and to abandon the traditional lecture. The reason is simple: most students cannot follow a mathematical argument for a fifty minute stretch. This is especially true in a lecture course which rarely breaks up naturally into fifty minute chunks. (As a result each lecture begins “Continuing the proof from where we left it last time...”)

So we invented the flipped workshop: students would be given material to study before coming to a workshop, where they would work in groups on mathematics exercises with guidance from a team of facilitators. The study material consisted of a specially written textbook and of audio tapes which took the student through the lessons in the book. The tapes provided the audio component of the lecture and the book the visual component. After each workshop students would attempt some homework problems which they would take to a small group tutorial. No lectures! The first presentation was traumatic, not least with the management of the audio tapes. The questionnaire returns were uncomplimentary, but interviews with students were revealing. In general students disliked two aspects: one was the pace of the tapes which they claimed slowed them down. Indeed they did – intentionally to the speed at which one can read mathematics. Further analysis showed that it was really the length of the tapes that was the problem. (They were each about an hour, as the corresponding live lecture would have been, albeit with the option to stop and rewind – but that would have made them even longer!) The second problem was the pre-class exercises. They were intended to be diagnostic – to tell us where students had not understood so we could provide support in the workshops and tutorials – whereas students wanted them to be “plug-and-chug”, presumably as evidence that they had done some work, or as a reward for working.

To cut to the moral for flipped learning (Bormann, 2014):

..., it was important to the teacher that the videos could be viewed in [less than] 20 minutes (Mason et al., 2013). How the teacher determined 20 minutes as the suitable amount of time was not clear. On the other hand, based on qualitative student feedback, more than 65% of students found the less than 20 minute duration to be an appropriate duration for the given content (Enfield, 2013; Mason et al., 2013). This was the case when videos were edited down to remove pauses and other redundancies. However, students’ preferred edited videos that were more concise to videos that were shot in one take (Enfield, 2013). It appeared the students valued production quality when considering its effectiveness for learning.

There is another important moral. Our expensively produced tapes were difficult to change, whereas the text was relatively easier to change (although the typing of maths text was at that time still painful). There needs to be a compromise between production values and the ease of redoing materials. We eventually abandoned the tapes keeping only the text and some pre-preparation multi-choice questions, but adding one introductory (live!) lecture for each section of the course.

We turn now to the main focus of the project, the observation of flipped learning at Leicester with a view to identifying the challenges of implementation. We carried out a number of class
observations, accompanied by questionnaires to students and interviews with staff. These illustrate the variety of interpretations of flipped learning, some of the advantages and disadvantages and some of the issues that need to be addressed. The questionnaire is appended to this report. For the record I note without comment that one member of staff who wanted to flip their lectures and be part of this project complained that the lecture capture software had turned out to be inadequate (for unspecified reasons).

**Ethical considerations**

Participation in the questionnaire and interviews by staff and students was voluntary. All the students involved were made aware of the purpose of the observations and questionnaires. We have tried to anonymise the lecturers concerned, although the small numbers of potential candidates makes this difficult without also omitting the discipline area: however, that would reduce the usefulness of the observations. Nevertheless, all the reports presented here have been approved by the staff concerned, in some cases with amendments for minor factual inaccuracies.

4. **The Observations**

4.1 **Natural Sciences**

The core programme is taught entirely by resource-based learning using a flipped methodology. Students are provided with a handbook detailing the required pre-session reading and questions to think about that would be discussed in class. This differs from the standard flipped classroom in that the discussion questions are given in advance to guide the reading. In addition, while some sessions have supporting video material, students are generally expected to prepare through reading.

Observations were made of a Natural Sciences class to inform the construction of the survey questionnaire. The class was a one hour session midway through a module. The session observed had 100% attendance (20 students). Students worked in apparently pre-formed groups, based on performance in previous modules⁶. Groups are changed for each module. (Modules run sequentially, so students study one core module at a time.) The material is delivered electronically so students have their laptops with them. Some groups (but not all) sit so they can easily share their screens. There was no whole class interaction: the facilitator visited each of the groups in turn, working at their own pace through the set questions in a room with moveable furniture and multiple electrical sockets.

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⁶ This is based on some unpublished research from Finland, which showed that very heterogeneous groups do not serve either the good students or the weaker ones.
Figure 1 Responses to the pilot questionnaire from year 2 Natural Sciences students. Note that none of the questions were answered “not at all”. Question 9 (on electronic communication) was added following the pilot.

Although attendance was 100%, groups appeared to vary in the degree of engagement. For example:

Student 1: “...I’m not sure what that means” Student 2 tries to answer looking at information on their screen ... “You’re changing the shape of the enzyme...” Student 3 buts in “... so it can bind to the other molecule” Student 2 asks for clarification of question. Student 1 explains. Student 3 adds detail – goes back to the prompting question and reads it out. There follows a discussion to which the fourth member of the group contributes

In contrast:

Another group is individually looking at their screens, mumbling about not understanding; one says “I can’t do this question.” They continue mumbling and looking at their screens until the facilitator appears.

The session ends with a class test.

A problem with a small cohort is that groups become de facto “friendship groups” which are known to be less effective in problem-based learning.

In response to questioning, two students independently say that they do not do all the preparation, because “if you do [all] the prep you’ve answered the questions already so there’s nothing to do in the class.” Their solution is to skim the recommended reading.
Another student says that the structure works well for biology, but “if you can’t do a physics derivation or understand an equation, it’s difficult to know how to ask for help”. The student suggests a mini-lecture for these topics.

The standard approach to flipped learning circumvents most of these problems. Concept questions are not provided in advance, although one might argue that the effectiveness of preparation is limited if it does not have clear objectives. Flipped sessions can include mini-lectures as required. This approach is often referred to as “just in time teaching” (Novak, 1999). On the other hand, advocates for the PBL approach might argue in favour of the individual attention provided by the facilitator.

For our next cases we observed two sessions, one a first year physics class and the other a first year class in mathematical techniques for physics.

4.2 Physics

This observation involved 130 students in groups of 5-6 seated around fixed tables with computer access. Attendance was close to 100%. There was one member of academic staff and 3 graduate assistants facilitating. The session lasted 90 minutes. Students worked through pre-set examples. The preceding lecture introduced the material but was not extensive in coverage or complete. Students were expected to prepare by reading the relevant sections of the set book; it had also been suggested that they look at the set problems in advance.

Group 1: (4F, 1M) They claimed to do some preparation generally, but had not done any specifically for this session. If they did prepare they did not assign the set questions to group members. “Sometimes” they did the set reading.

Group 2 (3F, 3M) This group claimed that they always did the reading and shared questions amongst the group in advance. They trusted their group members always to “have a go” at their allotted question.

Group 3 (2F, 4M) This group shared the set problems for the sessions in advance, with no sanctions for group members who did not prepare their allotted question. They had a single recorder (F) who had volunteered to write up the agreed solutions for all (!) sessions. They claimed not to use the set book in general but got their information from various notes instead (although this was not entirely clear).

Group 4 (2F, 3M) This group said that they each just looked over all the set questions as preparation. At the session they worked separately and compared their solutions. At this stage they did not use the set book much (although one student in the group did make notes from it). They used previous knowledge and lecture notes.

The session ended with the lecturer giving class feedback on the correct answers in a PowerPoint presentation. Groups exchanged in pairs their agreed solutions and peer marked each other’s, according to the presentation, on a scale of 0, 1/2 or 1 for each question. There was some chatter (presumably on topic) and some note-taking.
In discussion with the member of staff it emerged that there was more reliance on lectures than staff expect and less study of the textbook provided. This may be because a lot of the material is familiar at this early stage of the year. Generally students were engaged and on-task. The lack of clarity with what happened to the marks seemed to be intentional, so that the session was treated more as formative assessment. (In fact, students get an engagement mark for turning up and producing something, but group marks for correct solutions are not kept.)

Figure 3 gives the questionnaire results for the Physics class as a whole. With the larger cohort it is worthwhile to break the data down into subgroups depending on the amount of time spent on preparation. Figure 3 shows the results analysed in this way. Each question has four stacked bars. Using the same colour coding as in figure 2, the stack ranges from “entirely” (red shades), through “mostly” (green shades”) and “somewhat” (mauve shades) to “not at all” (blue shades). The four columns then correspond to the amount of preparation reported. From left to right these are: more than one hour; 30 to 60 minutes; 5-to 30 minutes; and less than 5 minutes (i.e. essentially zero). It may be helpful to have the numbers of students in each group: these were 25, 45, 34, 21 respectively. Thus almost half the class spent much less time on preparation than staff anticipate. This is likely to be at least in part because the subject matter is quite close to A-level, although with less scaffolding of the set questions.

Figure 3 Questionnaire results for a year 1 Physics class as a whole
One way to read the chart is to look to see where the groups of 4 stack differently. Those who did preparation (q3) did not do so because of time constraints (q4) but because they did not find it essential (q5), although they did find it useful (q6)! Those who did more preparation found that the session added to understanding. This is interesting: given the introductory nature of the content one might have expected that the students who had done the preparation thoroughly would find the session fairly redundant. Clearly, as is the intention in flipped learning, they felt the discussions added value. On the other hand, those who did little preparation also found the session useful (q10).

Note that students generally agree that preparation aids group collaboration (q8) although some students reported that their groups did not collaborate, a feature borne out by observation. Note also that electronic media were used to communicate by those who took the preparation most seriously (q9 fig 3).

4.3 Mathematical Techniques for Physics

As in case 4 this observation involved 130 students in groups of 5-6 seated around fixed tables with computer access. Attendance was almost 100%. There were three members of academic staff acting as floating facilitators. The session lasted an hour. Pre-session preparation included one lecture to introduce the material for the week. The material was provided in the form of a set text (written by the Department) including mathematical problems to be addressed at workshop and other tutorial problems for which solutions are submitted for marking. During the workshop groups write out
their agreed answers to the set problems. At the end they exchange papers in pairs and mark each other’s work supervised by staff using a 0, 1/2 or 1 scale for each question.

Four groups were observed, the first three randomly selected, the fourth by seeking out a group that did not seem to be engaging well. The first three groups shared questions to prepare in advance between their group members, with no sanctions if members came unprepared (apart from “shaming” or “make them work through it then and there”). Students did not seem sure if this procedure had been suggested to them or if it was the “obvious” thing to do. One group had finished the set workshop questions and were talking off-topic, in between working on the set tutorial problems together. Other groups worked individually on their tutorial problems. These three groups showed very good group cohesion and engagement (apart from one individual who was taking no notes and did not seem to be playing much of a role in the group). One group prepared a master copy of the work to be marked in the workshop and rotated the task of constructing this. Others appeared to just collate the individual scripts.

The fourth of the observed groups was stuck with meaning of “projection”. They “sometimes did some preparation”. One member had completed the questions but had failed to explain the meaning of projection to the group. There was little communication of understanding in this group: they appeared to be asking the facilitators for help individually. (Was this related to lack of pre-session preparation?) One member of the group had “googled” some material to try to find the meaning of “projection” but this had not engaged the group and was being looked at rather aimlessly. Some learning (how a vector was “normalised”) was however achieved in interaction with the facilitator, and within a subgroup while the facilitator was present.

We conclude that the engaged groups (more than 75% of the class) worked surprisingly well since the exercises in the text were not designed to be divided but built sequentially. It may be that the fact that the flipped structure runs through the whole programme in Physics means that students adapt to this way of learning. The three experienced academic staff facilitators were generally proactive in engaging with the student groups. The structure here is an amalgam of a form of peer instruction and flipped learning. The structure has been in place (with some modifications) for some 30 years. For much of the time the outcomes, measured by examination performance, were bimodal. In recent years this has changed with a compression of marks at both top and bottom giving a more normal distribution, but with almost all students achieving a pass grade on examination papers that have not changed in style or level over most of that time.

These students are the same cohort as for the Physics class (case 4). We decided not to take more time from their work to complete a questionnaire which would likely have the same results as for Physics, and even if it did not, the differences would be of only parochial interest in the Physics Department.

4.4 Engineering

This course is shared between two academic staff with one half delivered as a standard lecture course. About 30 students take the option. According to the lecturer, the preparation for the flipped part (now being delivered for a second year) involves reading the handbook and following the links for at least an hour, and for up to two hours for thorough readiness to participate. The handbook
comprises enhanced lecture notes from the previous years. The class sessions are run in a tiered lecture theatre for 50 minutes.

Attendance at the session observed was fairly poor (~30%), with the class predominantly international students. It was reported that the lectured component of the course also had poor attendance, although attendance was generally better in the second semester after the Christmas examinations. All the students at the class claimed to have read the handout (although the

![Figure 4. Results from the Engineering questionnaire. Only 8 students completed the questionnaire; bars in this figure refer to number of students. Darker shades (even bins) refer to students doing more than one hour of preparation; lighter shades (odd bins) to those doing less than an hour.](image)

questionnaire reveals that most had spent less than an hour on it). The sessions started with a short conventional lecture on the basic material (and some discussion of “housekeeping issues” for revision). A question was then presented on an overhead projector slide, and students given 40 seconds to think independently of the answer. There was a range of answers selected using flash cards, although some students were reluctant to participate, one of the two known problems with flash cards. (The other is the tendency to follow-my-leader.) This was followed by discussion with neighbours in which not everyone participated; the lecturer went round the groups. A new poll for the answer was unanimous and wrong (and was then corrected by the lecturer)! The procedure was repeated with two more questions. The lecturer indicated the relevance of the questions both to the subject and to the examinations. The session closed with a mini-lecture on the correct answers followed by the presentation and discussion of a computer simulation which students could find on Blackboard.

Without further research it is impossible to know the reason for poor attendance, but one may suspect that the issuance of full lecture notes may play a role, as we shall find in other cases below.
Students may find it difficult to know what they are missing if they believe themselves to be in possession of a “full” set of notes. Once again the students who spent more than an hour beforehand did not consider that they had fully completed the preparation (fig 4, q3). Overall the time spent on preparation was much less than expected by the lecturer (fig 4, q10), yet the students were satisfied that the class added significantly to their understanding.

4.5 Mathematics

The information here is based solely on a brief interview with the lecturer concerned. This was the first attempt by the lecturer at flipping the class, which was a third year option. The course did not go well, with students reluctant to do the preparation and protesting that they needed the lecturer to go through the material in the conventional manner. Much time was expended on discussions as to what was required of the students by way of assessment and how this was being supported in the absence of conventional lectures. The lecturer was however persuaded to increase the lectured component of the course. The students were able to pass a basic test and pass on material that they did not get lectured on but they had to do for themselves. To that extent there was some success in the module.

Again without further research it is difficult to make any definitive comment on this, but it is worth noting the similarity to the issues that some students have with the problem-based learning laboratory work in Physics, namely in believing that there is not one right answer and that they will be given full credit for following the processes appropriately. (In this case, making the correct deductions from the data they actually have, including the error estimates.) If the reproduction of lecture notes under examination conditions is now not the objective, students may need a lot of help in understanding what is. It may be that attempting to change the working practice of students in one module of their final year is a central issue, especially for the first such cohort, because of anxiety about grades.

4.6 Biosciences

The second level Research Skills course used to be taught by lectures alone. This has been changed to a short lecture course followed by weekly tutorial sessions. Preparation for the Bioethics tutorial requires students in groups to work through a number of case studies that illustrate various bioethical issues. In the workshop groups report their findings to the class.

The session was held in a large flat room with students in groups of 4-5 (a total of 44 students). It was led by one academic member of staff in a 50 minute slot. Group formation was mixed.

Initially there were no volunteers to begin, so a group was picked at random. Only one student from the group spoke with no time limit. There was no class response so the lecturer summarised the issues from a prepared script. A second group then volunteered. They shared the questions arising from this case around the group so all spoke to the class and it was evident that they had all done the class preparation. Eight groups proceeded in this fashion. One group had done additional online research. There was very little note-taking, but most students seemed to be listening. All students interviewed claimed to have done the preparation, either individually or in some cases together as an organised group.
The figure (fig 5) shows the questionnaire results. The responses for each question are split between students who reported that they did more than one hour in preparation (odd columns) and those that reported that they did less than one hour (even columns, lighter shading). Interestingly, those that took less time were more likely to believe that they had completed the preparatory work (q3) and were clearer about what was expected. They also claimed to get more out of the session (q10). The structure relies on face-to-face lectures for delivery of the basic content and there was little class discussion beyond presentations, so it goes only some way towards the flipped ideal (“back flipped?”) The lecturer considered it to be a major improvement over the previously lectured content. However, this tutorial forms part of a larger module in research methods, delivered in part by team-based learning, which, as we have seen (section 2) incorporates the main pedagogical aspects of the flipped classroom.

4.7 Education

A postgraduate Research Methods course was discussed with the lecturer. The module comprises 10 units each of which follow an identical pattern. The pre-session work involves either an on-line lecture or a reading assignment that should take students one to two hours. Pre-session reading is particularly useful for international students for whom English is a second language.

Sessions are then spread over the following one to three days and include mini-lectures as required. After each session students are set two to three hours work. Thus most of the learning takes place in class time and in groups. The curriculum is very fluid (“emergent” was how it was described) with a large input from students. For large classes repeated PowerPoint presentations are avoided by having students submit their slides for assessment.
The lecturer finds that production of the voice-over PowerPoint slides for the pre-session preparation is easy, but requires a long planning time. They are not recordings of live lectures put online. Therefore, flipping was undertaken as part of a (continually revised) rolling programme.

4.8 Chemistry

Chemistry have a course taught by problem-based learning in year 1, which follows a flipped pattern and has run in various forms for several years with positive student evaluations. Recent developments have included student participation in developing the course. There is also a course taught in flipped mode which follows the more standard flipped classroom structure: students study set reading prior to the lecture which then focusses on concept questions. In this example, individual students were selected to answer the questions. This differs from the usual approach in which students are presented with multiple choice answers and personal response units (“clickers”) are used to show histograms of the choices on the projector screen. The lecturer can then proceed on the basis of the responses. The singling out of individual students and has turned out to be not much liked by and will be changes to team answers next year. In addition, this Level 1 course has been less successful this year as the students did not fully engage with the pre-lecture reading. Flipped lectures were tried in one Chemistry course at level 4 for the first time this year and were particularly successful with good student evaluations. Because of scheduling issues we did not get to observe the flipped teaching in Chemistry.

5. Flip at other institutions: some examples

5.1 Chemistry at Birmingham University

The Inorganic Chemistry for Biology is a large class shared between two lecturers both of whom decided to flip. Videos of the previous year’s lectures were posted on line as preparation together with a set of multiple choice questions and some free text questions from the videos. They were delivered as one session per week, each one hour, eight in total. This schedule gave (or should have given) adequate time for pre-session preparation.

In-class activities involved clicker questions and peer instruction. Since flipped classes work best where the material is conceptual, only some of the sessions were flipped. There were some problems with preparation and attendance with a number of students choosing between the two, but not both. Interestingly the lecturers used a VARK learning styles questionnaire to gather data on students in order to investigate any relation between preferred styles and satisfaction with flipped learning, but the results are so far unpublished.

5.2 Chemistry at the University of East Anglia

At UEA a chemistry lecturer has decided to flip his module. Screencasts of lectures from the previous year were edited as a pre-session resource. It took several years’ experience of flip to refine the in-class questions. In order to get students to engage, these should not be trivial recall questions; the thinking behind the flipped class is that it makes time for higher level discussion. Thus, the lecturer needs to develop conceptual questions that not everyone in the class can answer correctly. Once a question is posed, and an initial poll taken, animated discussions follow. Polling again should
see a shift, usually to right answer. In fact, typically 80% of the class will get the answer correct at this stage. The lecturer can then explain the point to the class. This can work with various technologies, but the use of smart phones, for which there is a variety of software, gives an immediate response without the need for the hardware of “clickers”.

The lecturer argues that putting more of the material out of the sessions is a way to make students do the preparation. It is important that the classes are not such that students can substitute attendance at the lecture for preparation. In order for students to turn up to the class – having gone through all the material in preparation – the class must be worthwhile. This means that the questions must be limited in number and challenging.

5.3 Physics at Edinburgh

The year 1 physics class at Edinburgh involves 250 to 300 students taking the subject for one third of their programme. Since the first year physics is common to many programmes, more than half of the students do not continue with Physics in later years: many have signed up for Engineering and other sciences. All the first year Physics is flipped, as is the year 1 Astronomy taught in the same Department. The Physics is taught by three academic staff in three 50 minute sessions each week together with a weekly three hour workshop.

Some flipped learning continues into later years: the year 2 Mathematics for Physics is flipped and there is some of what one member of the team refers to as “pseudo-flipping” in higher years. Students see flipped learning as the normal way of doing physics in year 1, but there are then issues around adaptation to traditional teaching in subsequent years.

Staff were brought on board by flipping the structure of the programme (as in the introduction of resource-based learning in Physics at Leicester). Indeed, as in Leicester, the actual implementation in the classroom is “variable”. It does require engaged instructors. But it has encouraged staff in general to depart from all chalk and talk towards more interaction.

The key to successful flipped classes is in the writing of the in-class questions. This is something that all practitioners agree upon and in most cases it is something that has developed with practice. It is not useful to ask about facts in the class; discussion questions need to be about procedure (do something), conceptual understanding or linkages between ideas. (They need to be something that can be discussed.) This does not mean they cannot be quantitative. This is probably best illustrated by an example:

The First Law of Thermodynamics. 10J of energy are added to an ideal gas; the internal energy changes by 8 J. How much work is done by the gas +2 J, −2 J, + 12 J, −12 J?

(If students jump to the equation, they need to get the signs right; so this teaches them also to think about the answer.)

For pre-session preparation students have a full set of lecture notes and problems in advance. Targets are set a week ahead, including which calculations to do and which problems to try. Videos are used, but only sparingly. A clear expectation is communicated to students that the preparation will be done; it appears that students learn the game. However, attendance has been a problem this year (~60% compared to 90% last year) but this may be reflecting an Institution-wide issue.
5.4 Mathematics at Edinburgh

The lecturer here has changed from going through problems in workshops to pre-workshop preparation. Students are expected to spend 6 hours per week in private expected study with 6 hours per week of contact time. Private study now comprises some pre-workshop preparation as well as some assignments.

More students now do the required preparation – only 3% do less than one quarter of the required work. So there is more time on task.

If we count the examination as a criterion for success then it is notable that the pass rate has crept up, apparently requiring the lecturer to set a harder exam! There has been a positive response in course evaluation with only a small vocal hard core of opposition (5%).

6. A flipper’s guide

Based on these observations and on the literature we offer by way of conclusions the following guide to the flipped classroom. Some of the content of this section is taken from Waring and Evans (2014). Gerstein (2012) looks at flip in relation to the experiential learning cycle; Bretzmann (2013) collects many experiences of flipping in different subjects. Much of the literature refers to US experience at high school level which may have little relevance to UK undergraduate programmes. Bormann (2014) gives a meta-analysis of research on flipped learning which is mainly based on data from higher education.

(a) Keep it short (see above)

It does not have to be video-based, but it helps. We have found the use of short video introductions to prescribed reading enhances engagement (Williams, unpublished). Voice-over PowerPoint can be straightforward and effective and can be produced without editing. Students prefer picture-in-picture of the lecturer rather than a disembodied voice. Audio quality is absolutely crucial: if you cannot get the sound right, do not bother with videos. One of the authors uses Camtasia with its editing functions. This is more time consuming, but probably worth it if students are expected to watch a lot of video. Muller (2008) claims that students like two person presentations. Personally, one of us has tried this and it is great, but it proved impossible to make it cost-effective in terms of the preparation and production time required.

The evidence from the use of MOOCs (Massive Online Open Courses) in campus-based blended learning is that long videos of live lecture presentations are not watched prior to classes, but are principally used for revision.

(b) How to encourage students to prepare

The evidence from the literature is that participation in preparation rates of around 80% are good. Some implementations use various forms of admission test, for example online MCQs, or a team-based learning approach. One tactic is to be ruthless in assuming that students have done the preparation and not be tempted to turn the class into the lecture for the benefit of those who have
not (and the dis-benefit of those who have). That way the 80% of the class who are prepared will have every reason not to turn up. Sessions should effectively begin with the first concept question.

To get 80% participation Waring and Evans (2014) offer the following advice:

- set highly focussed pre-session tasks (“not sure what we were supposed to do” is an appeal for a lecture)
- give clear directions to resources (“we couldn’t find it in the library” “it wasn’t in our edition”)
- set manageable tasks (in the Natural Sciences programme we have control of the scheduling so we can ensure students have time to complete pre-session activities; even so, we have been guilty from time to time of expecting too much)
- set appropriately scaffolded activities to support progression over time
- provide multiple resources
- consider carefully the design of videos to be fit for purpose (which includes being clear about the purpose)

(c) How to encourage attendance at class sessions

- provide opportunities for students to discover what they know and what they do not know
- ensure that questions explore higher cognitive levels
- ensure a continuing cycle of learning by following up in subsequent sessions on issues raised by students

As we reported above, the lecturers from the other institutions we talked to noted the difficulty of writing good in-class questions. The suggestion was that these take time and experience to develop.

(d) What to do about notes for revision

This is not an issue that is widely raised. But we need to remember that, whatever the failings of lectures, in theory, in a traditionally taught course, students can use the notes they take from well-prepared sessions for revision, knowing that they would cover everything that might come up. Will in a flipped approach students probably need to be guided to take appropriate notes from the videos (or other media) using pro-formas or seed questions. In the Natural Sciences programme we provide guidance to students on note-taking as part of their personal tutor support. It can be revealing how much help some of them require in making effective notes when it is not just a matter of copying it down from the board.

(e) How to get started

As we have seen flip-like approaches do not have to use video, but it helps. One way to get started is to record lectures one year and flip the classes the next. Personally we hugely dislike multiple presentations of 50 minutes of unedited footage; they are rarely fun to watch even if the live performances were masterpieces. According to the literature, students find 20 minutes about the maximum length, although feedback on our own videos suggests that around 10 minutes is better, possibly because this forces the presenter to think about the content of each section. So our advice would be: at the very least edit your live performance.
Rather than editing a live lecture, it may actually be less effort to record a narration to a set of PowerPoint slides afresh. However, unless this is done in quite short takes we find that it is desirable to have a prepared script. However, this then needs practice at delivering it in a way that does not sound like it is being read. (Reading the autocue is not the same as giving a speech.) We have used Adobe Presenter (useful if you do not have a local VLE), PowerPoint and Camtasia (with its editing facilities). It is important to check that all students will have access to the videos – i.e. that they play across enough platforms – and to provide students with this information, in order to avoid having to host a technical support centre for the first few classes.

(f) Finally, the most important rule

Ensure buy-in from your students.

It is important to clarify the purpose and value of the approach and to make sure that students know exactly what is expected, that it is achievable, and that they know how to achieve it. Even then, it is necessary to accept that there will still be some students who will not appreciate your efforts. (But then perhaps not every student raved about your lectures.)

7. Conclusions and future directions

Gibbs (2010, 2012) is quite emphatic that research has provided clear evidence of the principles that underlie good teaching. In a word they involve encouraging student engagement in the process of learning. The problem remains of how to put these principles into practice with large classes and limited resources. The flipped classroom is one attempt to do this. Its merit is that it can be implemented without large investments or changes to the university structure. In this respect it is unlike other forms of experiential learning.

Our observations seem to point to multiple rather different approaches to putting flipped learning into practice. Most of these met some problems on their first trial; there is a danger that this will reflect on – or be perceived to reflect on – NSS scores and therefore discourage experiment. The first lesson therefore seems to be to involve students in the rationale for changes to pedagogy and to make sure they understand exactly what is expected of them and why.

The second lesson from our interviews and observations is that classroom activities have to be thought out and refined in the light of experience. It is possible to make a difference. One of our more experienced contributors achieved a spontaneous standing ovation from a large class of students at the end of a flipped course of lectures.

This suggests that there needs to be an on-going sharing of practice. As far as we know, none of the practitioners at Leicester have spoken to each other. It may be that a good next step would be the provision of some central support for staff wishing to embark on flipped learning.

As has probably been clear, writing this report has been very much a labour of love for us. We believe that the nature of university education needs to change, and will change, and that at last, after many false horizons, the technology can now serve to achieve this. Just as printing
democratised knowledge by making it more readily available, so will almost free video technology widen access to higher learning, and lead to higher participation rates at masters’ level and beyond.

Bibliography

Flipped learning has been used in the full range of disciplines, in literature, mathematics, science and so on. However, much of the literature concerns experiences at college level in US schools. Searey (2013) and Lancaster (2013) are a couple of brief introductions to practice in HE.

A few useful web sites are

http://www.cvm.umn.edu/facstaff/prod/groups/cvm/@pub/@cvm/@facstaff/documents/content/cvm_content_454476.pdf

https://docs.google.com/document/d/1arP1QAkSyVcxKYXgTJWCrJf02NdephTVGQltsw-S1fQ/view

http://flippedlearning.org/site/default.aspx?PageID=1

Searching the University Library’s EBSCOhost digital resource using the British Education Index or ERIC digital repositories for variations on “flipped classroom” yields large numbers of research papers that can be sifted for university level and discipline specific results.

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Appendix: Flipped learning Questionnaire

How many minutes did you spend preparing for this session? [ ]

<table>
<thead>
<tr>
<th>Question</th>
<th>Entirely</th>
<th>Mostly</th>
<th>Somewhat</th>
<th>Not at all</th>
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<tbody>
<tr>
<td>The instructions for the pre-session preparation were clear.</td>
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<tr>
<td>Were the instructions for the pre-session preparation provided in good time?</td>
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<td>Did you complete the pre-session preparation?</td>
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<td>Did your teaching schedule allow enough time to prepare for the session?</td>
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<tr>
<td>Was the preparation essential for the session?</td>
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<tr>
<td>Was the preparation useful for the session?</td>
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<tr>
<td>Were you expected to collaborate in the session?</td>
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<tr>
<td>If collaboration in the session was expected, did the preparation allow you to collaborate effectively in session?</td>
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<tr>
<td>Did you use social media/ electronic communication (facebook, email, twitter etc.) to discuss the preparation?</td>
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<tr>
<td>Did the session itself add to your understanding of the topic?</td>
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Do you have any other modules which require similar pre-session preparation? Yes/no