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Flipped Learning Boosts Exam Performance for Students with Lower Previous Academic Attainment

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Flipped learning, constituting pre-session preparatory work in the form of videos, presentations and directed reading, was compared with traditional teaching methodology, transfer of subject knowledge in face-to-face sessions followed by post-session application and consolidation. Flipped learning, as part of the delivery of a level 3 biology course to young adults, was demonstrated to increase the opportunity for higher order thinking activities during sessions and was perceived by students to encourage independent thinking. Attainment in examination questions covering curriculum areas delivered by the alternative pedagogies revealed a 12% mean increase in scores for flipped topics across the cohort, with the greatest impact evidenced by students with lower previous performance in general science examinations (17% increase). Thus, flipped learning may be an effective approach to maximise the cognitive value of face-to-face time with students, encourage the development of independence, and raise achievement, particularly for those students with lower levels of previous academic attainment.

Introduction

One of the challenges in delivering level 3 science curricula is that, due to the demands of covering an extensive syllabus in a limited timescale, a large proportion of face-to-face session time may consist of direct instruction with less time available for applying, analysing, evaluating or linking together the knowledge acquired. Furthermore, the volume of curriculum content required, and the speed of delivery necessary, to prepare foundation year students for year 1 study, can be overwhelming (Allan, 2018).

Flipped learning is defined as moving direct instruction from the group learning space into the individual learning space (Hamdan *et al*., 2013). The flipped teaching model consists of students completing independent study activities before a session as preparation, often in the form of watching videos, rather than afterwards as consolidation, as in traditional style teaching. The flipped pre-work intentionally deals with lower order thinking tasks: acquiring the basic information required to access the session, allowing a deliberate focus on activities which

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promote higher order thinking during sessions: taking the knowledge, manipulating it, debating, evaluating and applying it. Thus, flipped learning has been said to "flip the triangle" (Fulton, 2014, p. 26), as during traditional sessions, the lower order thinking skills of remembering and understanding, found at the bottom of the triangle in Bloom's revised taxonomy (Bloom, 1956; Anderson and Krathwohl, 2001), take up a large proportion of face-to-face time, with the higher order thinking tasks of applying, analysing, evaluating and creating, found at the top of the triangle, often taking place during independent study time when students are working on their own without the support of lecturers and peers (Figure 1).

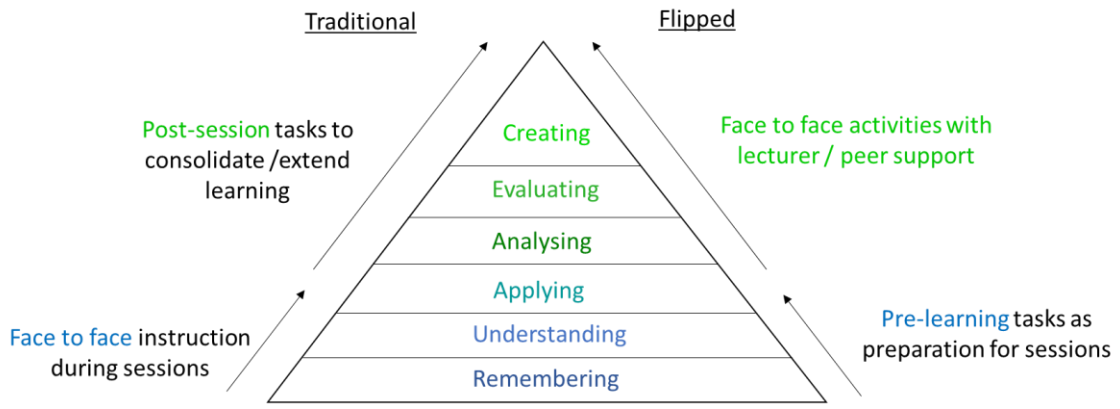

Figure 1: Flipped learning may enable more time for higher order cognition during face-to-face sessions.

The flipped method is supported by the pedagogical theory of priming, which suggests that when learners are exposed to a particular stimulus, their recall of that stimulus is improved due to their previous experience (Bodie, Powers and Fitch-Hauser, 2006). In other words, when students have been introduced to key learning points during their flipped pre-work, they are 'primed' to learn more effectively when they re-engage with them during sessions.

The flipped learning approach initially arose when two chemistry teachers began recording lectures for students who could not attend their classes (Bergmann and Sams, 2012), and evidence of the power of flipped learning is now mounting. For example, increases in pass rates in a range of subjects have been reported: 19% in English language and science, 13% in maths and 9% in social studies, when videos are used as pre-session preparation with collaborative problem solving during face-to-face sessions (Pearson Education, 2013). In addition, Chao, Chen and Chang (2015) reported that flipping part of a computer-aided design curriculum resulted in improvement not only in students' attainment, but also their attitudes to learning and motivation, while the academic performance of advanced placement chemistry students also improved following a flip intervention, with the ability to pause, rewind and review video lectures perceived by the students as advantageous (Schultz *et al.*, 2014). In terms of maximising the use of face-to-face time with students, Garver and Roberts (2013) designed flipped lessons for their maths students involving podcast style flipped homework, followed by electronic classroom response system, or 'clickers', based quizzes, which required higher order thinking to complete, reporting that this approach enabled over 90% of class time to be devoted to the top two levels of Bloom's taxonomy. Furthermore, Lax, Morris and Kolber (2017) reported that partially flipping a session during an introductory biology course resulted in a 25% increase in active learning. Investigations into flipping foundation chemistry topics suggested improvements in learner attainment for simpler aspects of the curriculum, but little evidence of impact for more complex topics (Allan, 2018).

A number of trials of flipped learning have not found any impact on student attainment, for example, DeSantis *et al.* (2015) reported no significant differences in the 'learning outcomes' of geometry students taught using either the flipped or traditional method and Clark (2015) did not detect any difference in maths attainment following the flipped model, although they did note improvements in student engagement and communication. Intriguingly, an extended analysis by Sergis, Sampson and Pelliccione (2018) of previous flip interventions involving ICT and algebra curricula (Katsa *et al*. 2016; Kostaris *et al*., 2017) suggested that flipped methodologies may have most impact on students who find meeting the learning outcomes more challenging, by providing the tools to keep pace with higher-performing classmates.

The current study thus aims to evaluate the impact of the flipped methodology on both the opportunities available to develop higher order thinking skills during face-to-face sessions, and any impact on students of varying abilities within the cohort.

Materials and Methods

Half of a level 3 biology curriculum, delivered to a small cohort of 18-19 year old students was taught using the traditional style of delivery, with the subject knowledge introduced and explained during face-to-face sessions and 'exam-style' questions, sourced from previous end-of-year assessments, set as post-class consolidation work. The other half of the curriculum was delivered using the flipped method, with pre-class preparatory work consisting of a mixture of materials: directed reading (textbooks and science articles), presentation slides, videos created specifically for the cohort and videos selected from online libraries. The flipped sessions consisted of interactive, student-centred discussion and debate, application of knowledge through case studies, and collaborative completion of practice exam questions, also sourced from previous assessments. The curriculum areas taught using each method were chosen at random by an independent educator who, to avoid any unintended bias, was not aware of the research question. All face-to-face sessions were delivered by the same person to the same cohort of 18 students, to avoid any impact of variation in teaching quality, or the academic profile or teaching style preferences of the cohort.

Opportunities for higher order thinking during teaching sessions were measured by a second independent educator, who recorded the time in minutes that was spent on activities that required lower order thinking skills, with reference to Bloom's revised taxonomy (Bloom, 1956; Anderson and Krathwohl, 2001), and the time employed on higher order thinking activities. At the end of the academic term, students sat a mock exam (as part of their normal assessment preparation), which included questions on the content covered in both the traditional and flipped sessions. The percentage of marks awarded were compared between the curriculum areas covered by the traditional and flipped sessions and used as a measure of student attainment. Furthermore, for analysis purposes, the class was divided into 'high achievers', defined as students who had achieved A or A* grades in their science GCSEs and 'standard achievers', defined as students who had achieved B and C grades. None of the students had achieved lower than a grade C in GCSE science and there were no students with any previous experience of studying science subjects at level 3. The exam paper was selected randomly by a third independent educator who was also unaware of the research question, from a selection of 'past papers'. In-class quizzes and activities devised by the delivering academic were not used, in order to avoid any possibility of bias, and formative assessments conducted during sessions were not used, as the consolidation following the traditional sessions forms part of the students' learning, hence any method of assessment should take place after the full learning experience is completed. The attainment results were first analysed using the Shapiro-Wilk test for normal-

ity and found to not be normally distributed ($W = 0.81$, $p < 0.05$). Therefore, the non-parametric Wilcoxon signed-rank test, with Bonferroni corrections, was employed to compare attainment in exam questions that covered the curriculum areas taught by the two different teaching methods.

To investigate the students' experience of the two alternative approaches, an anonymous questionnaire was completed. Students were asked to respond to six statements, when considering each approach, by selecting a number from 1 to 4 (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree). The statements were: "I enjoy teaching sessions", "sessions prepare me for exams", "I learn from interacting with my peers", "I learn with the support of teaching staff", "sessions encourage independent thinking" and "sessions make the best use of my time". There was also an open response box in which students could write any comments they had about either approach.

Results

An impartial educator recorded the number of minutes during traditional and flipped sessions that were spent on activities requiring lower order or higher order thinking (Figure 2). During traditional sessions, a mean of 13 minutes out of 60 (22%) were spent on higher order thinking tasks, which mainly took the form of mini episodes of formative assessment, such as multiple choice quiz questions. During flipped sessions, a mean of 49 minutes out of 60 (82%) were employed in higher order thinking activities and included more sustained periods of analysis; for example, when working towards the learning outcome of 'interpreting data on blood cholesterol levels and cardiovascular disease' students reviewed the efficacy data on the use of statins in controlling cholesterol levels and debated the current NHS guidelines on the prescription of these drugs.

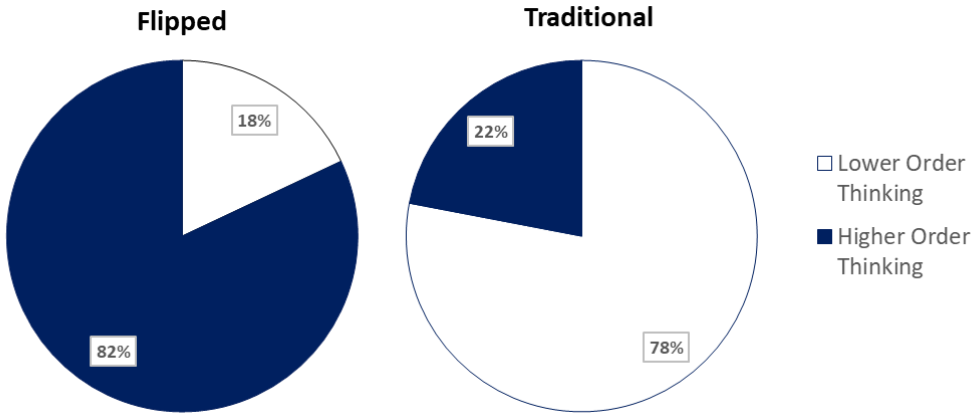

Figure 2: Percentage of face-to-face time spent on lower order or higher order thinking activities during traditional and flipped sessions.

At the end of the academic term, students sat a mock exam, which included questions on the content which had been delivered in either traditional or flipped sessions. Student attainment overall (mean % score for the cohort) was 12% higher in questions where the curriculum content was taught in flipped sessions (88%) rather than traditional sessions (76%), constituting a statistically significant difference in attainment (Wilcoxon signed-rank test with Bonferroni correction, $W = 15$, $p = 0.01$). Of the 18 students, 13 achieved higher scores in the flipped curricu-

lum areas, three students achieved higher scores in the traditional curriculum areas and no difference was detected for two students. However, the students whose attainment was the same for each method achieved a score of 100% in curriculum areas taught by both methods, meaning that it was impossible to ascertain which method was the most effective for these students. The data was further analysed by dividing the students into 'high achievers', who achieved A or A* grades in their separate science GCSEs and 'standard achievers', who achieved B and C grades (Table 1 and Figure 3).

STUDENT	PRIOR ACHIEVEMENT	TRADITIONAL SCORE (%)	FLIPPED SCORE (%)	DIFFERENCE (%)
1	High	92	89	-3
2	High	83	100	+17
3	High	100	100	0
4	High	92	89	-3
5	High	100	78	-22
6	High	83	100	+17
7	High	75	100	+25
Mean (high prior achievers)		**89**	**94**	**+5**
8	Standard	83	89	+6
9	Standard	92	100	+8
10	Standard	67	100	+33
11	Standard	100	100	0
12	Standard	75	100	+25
13	Standard	75	89	+14
14	Standard	25	33	+8
15	Standard	42	78	+36
16	Standard	50	89	+39
17	Standard	75	78	+3
18	Standard	67	78	+11
Mean (standard prior achievers)		**68**	**85**	**+17**
OVERALL MEAN		**76**	**88**	**+12**

Table 1: The percentage of marks attained by each student in exam questions where the content was delivered using either traditional or flipped pedagogy.

Of the 11 'standard achievers', 10 scored more highly in the flipped questions with the remaining student achieving 100% in all questions. The mean score for 'standard achievers' was 17% greater in flipped areas of the curriculum (85%), compared to traditional areas (68%) and the difference in attainment was statistically significant (Wilcoxon signed-rank test with Bonferroni correction, $W = 0$, $p < 0.01$). Of the seven 'high achievers', three achieved higher scores in the flipped areas, three achieved higher scores in the traditional areas and one achieved 100% in all questions. However, student 5, who was one of the three students who achieved higher scores in the traditional areas, and in fact showed the biggest difference in attainment of all the 'higher' achieving students, was 15 minutes late starting the 60-minute exam. By the student's own admission, they rushed through the last few questions, which happened to be those representing the curriculum areas taught by the flipped method, whereas the questions taught using the traditional method were nearer the start. Therefore, it could be suggested that this student did not perform as well in the flipped areas due to a lack of time rather than as a consequence of a different style of delivery. The mean attainment of 'high achievers' was 5% greater in flipped areas (89% traditional, 94% flipped), a much smaller difference than for the standard achievers (the sample size for 'high achievers' was considered too small to report meaningful statistical analysis).

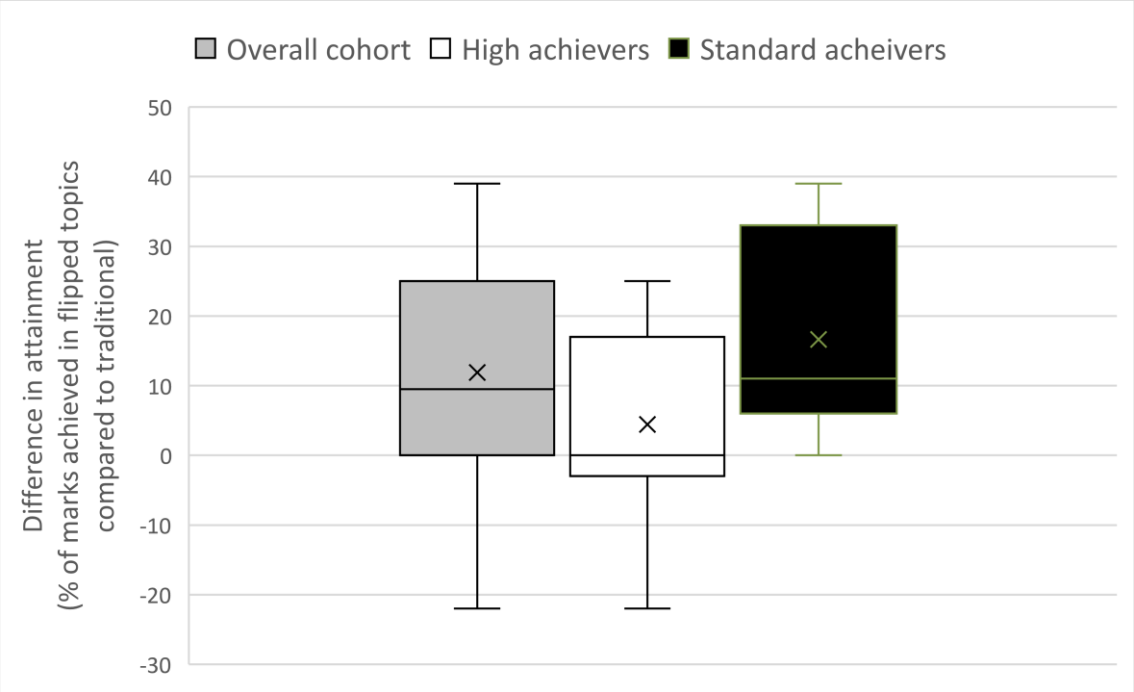

Figure 3: Difference in attainment between curriculum areas delivered by flipped learning compared to traditional teaching methods. Data is shown for the overall cohort, and subdivided into students with high previous attainment and standard previous attainment. Whiskers represent the range, the boxes represent the interquartile range, the cross represents the mean difference, and the bold line represents the median difference.

Finally, the students' perception of their experiences of flipped and traditional learning was surveyed using an anonymous questionnaire. Students considered six statements with regard to each teaching method by selecting a number from 1 to 4 (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree) and the responses were combined to produce a cohort mean for each statement. Questions relating to enjoyment of sessions, preparation for exams, learning with support and effective use of session time revealed very little difference in the

mean scores reported. Students appeared to either perceive no difference in these measures between the two styles, or an approximately equal number of students preferred each, thus, no overall preference for either the flipped or traditional styles emerged (Table 2).

STATEMENT	**MEAN SCORE**		**PERCENTAGE OF STUDENTS GIVING EACH TEACHING STYLE A HIGHER SCORE (%)**		
	Traditional	Flipped	Traditional	Flipped	No difference
I enjoy sessions	3.3	3.2	28	22	50
Sessions prepare me for exams	3.3	3.1	17	11	72
I learn from interacting with my peers	3.1	3.4	22	39	39
I learn with the support of teaching staff	3.2	3.2	11	11	78
Sessions encourage independent thinking	2.8	3.7	0	67	33
Sessions make the best use of my time	3.0	3.3	17	33	50

Table 2: Mean scores and percentage of students giving traditional or flipped style sessions a higher score in a questionnaire on the students' experience of flipped learning.

The biggest difference in mean score (2.8 for traditional, 3.7 for flipped) was for the statement regarding encouragement of independent thinking. Furthermore, 67% of the students gave the flipped approach a higher score for this measure, with 33% reporting no difference and no students giving the traditional sessions a higher score. Open text comments revealed that students' experiences of the two session styles was varied, with some preferring traditional and others preferring flipped (Figure 4).

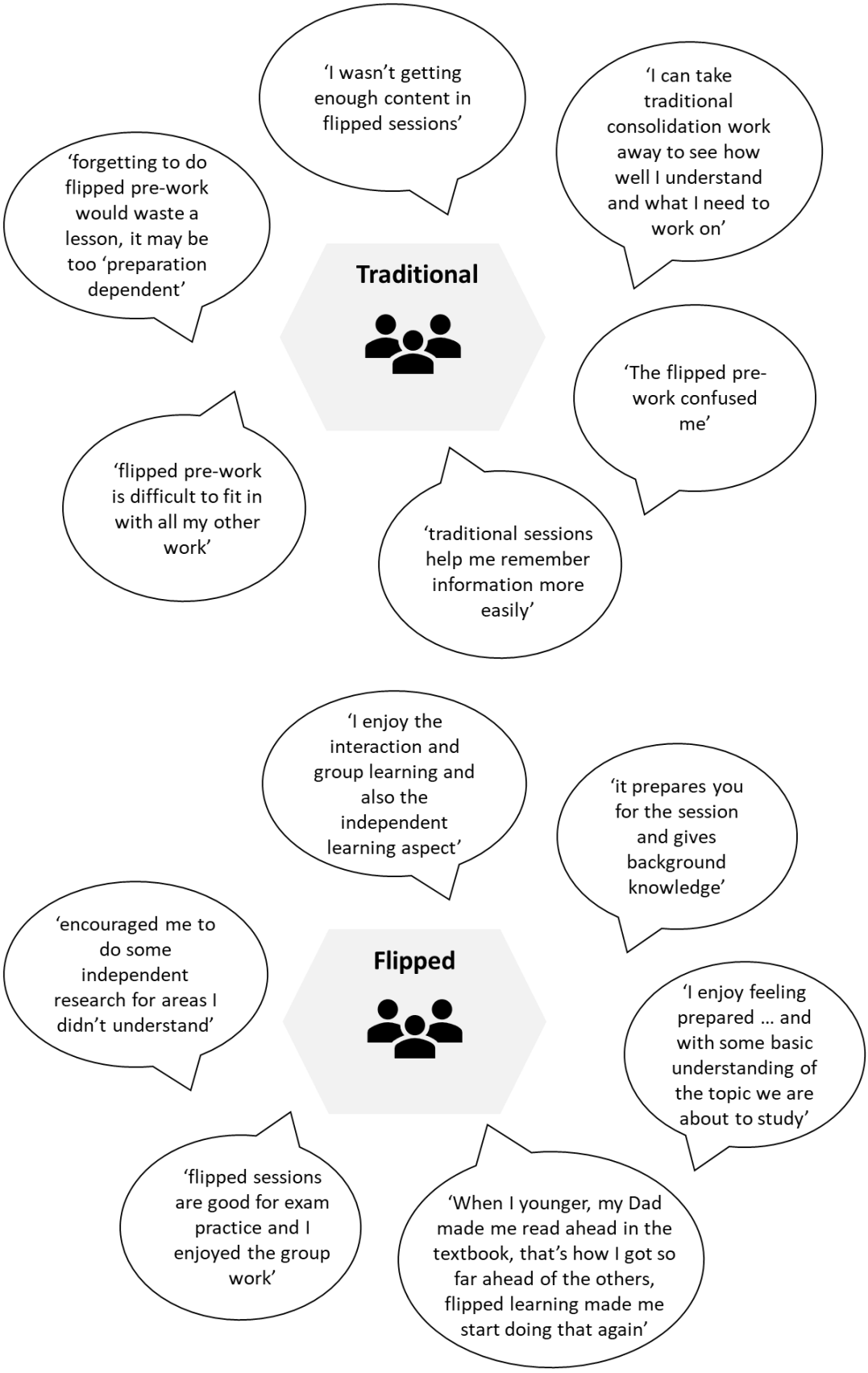

Figure 4: Student questionnaire responses showing their preference for traditional/flipped style sessions.

Two students commented that a combination of delivery styles in the future may be most beneficial to their learning, suggesting that the topics they feel most confident about accessing independently were the most appropriate for flipped learning.

> "I would like to start topics with some traditional sessions and have some flipped towards the end"

> "traditional works better for more complex ideas, whereas flipped was good for lifestyle topics"

Discussion

Observations of teaching sessions utilising either traditional or flipped pedagogies revealed a striking difference in the percentage of face-to-face time that was spent on higher order, rather than lower order, thinking skills suggesting that the practice of students completing pre-class preparatory work enables a large increase in the amount of session time which can be assigned to developing higher cognitive skills, such as analysis and evaluation. There were numerous examples of students debating and justifying their opinions, opportunities for peer feedback, time to explore not only the meaning of data at face value, but also the legitimacy of the data sources, alternative interpretations, implications, ethical concerns and relevance to current debates in science and healthcare.

Furthermore, analysis of student attainment suggests that, while overall cohort scores on exam questions increased for areas of the curriculum delivered during flipped sessions, the impact was the greatest for the 'standard', rather than the 'higher' achievers. Thus, it is possible that students who have not achieved as highly in previous educational settings may have more to gain from the adoption of flipped learning in their future education. This could be because these students benefited the most both from the opportunities to engage with the curriculum content at their own pace in the pre-class preparatory work, and the increase in time devoted to developing higher order thinking skills during sessions. Perhaps their attainment was higher in the flipped areas of the curriculum because they were more proficient at applying their knowledge and evaluating the contexts presented in the mock exam as they had more time to develop the skills required to do so during sessions. It could also be postulated that the most highly achieving learners are more resilient to differences in teaching style and will learn and achieve however the curriculum is presented, while the slightly lower attaining will show a greater response to a teaching style that either does or does not meet their needs.

An alternative interpretation of these results could be that the students' prior achievement at GCSE, which was used to categorise them as 'high' or 'standard achievers', is actually an indicator, not purely of ability, but also of response to teaching style, as all the students in the study confirmed that the GCSE provision they had received in schools had been taught using a traditional style of delivery. Thus, perhaps the students whose learning preferences are best suited to the traditional style achieved the highest grades at GCSE, whilst those students who are more suited to a flipped method did not achieve such high grades. It should be noted that the reported increase in attainment in the flipped areas of the curriculum could have been influenced by the curriculum areas taught using each method, although every attempt to mitigate this risk was in place, and topics and exam questions were chosen randomly by an independent educator. However, repeated studies with multiple cohorts and settings would be a valuable next step.

Student feedback revealed no overall cohort preference between the two methodologies in terms of enjoyment, support for exams or interactions with others. It was evident that some students were more comfortable with the traditional method of delivery, stating their anxiety over acquiring knowledge independently as pre-class work and concerns regarding the pre-requisite of completing the preparatory work to access the session. Other students simply stated their preference for the traditional pattern of an introductory teaching session followed by independent consolidation. On the other hand, many students responded positively to the flipped method, reporting their enjoyment of the more interactive nature of the sessions, their appreciation of feeling prepared in advance of sessions and the increased emphasis on independent learning. In fact, approximately two thirds of the cohort found that flipped learning encouraged independent thinking, with no students rating traditional sessions more highly for this measure, confirming the observation that flipped sessions encourage the development of more advanced cognition than simply passively acquiring the knowledge being presented. Helping students learn how to learn (Thomas *et al*., 2015) as they enter Higher Education, can only be an advantage in supporting their future success.

Conclusion

The results of this study suggest that flipped learning makes a large increase in face-to-face time available for higher order thinking activities, that students perceive that flipping the learning encourages their independent thinking and that higher scores are achieved in exam questions where the curriculum content is taught in flipped sessions, especially by students with lower levels of prior academic attainment. Students had a mixture of opinions towards the different teaching methods, with some students feeling best suited to the traditional style of delivery and some preferring flipped learning, but there was no overriding preference, suggesting that an increase in attainment can be achieved whilst maintaining overall student satisfaction. Furthermore, providing high quality online teaching during the Covid pandemic has resulted in a leap forward in many teachers' digital capabilities, along with a rise in students' confidence in accessing information at home (Iivari, Sharma and Ventä-Olkkonen, 2020). Could this, therefore, be the moment to harness the power of flipping the curriculum to ensure that face-to-face time with students is cognitively rich and to boost exam preparation for those students who have the most to gain?

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