Harper *et al. Int J Educ Technol High Educ* (2024) 21:2
https://doi.org/10.1186/s41239-023-00435-0

International Journal of Educational Technology in Higher Education

RESEARCH ARTICLE Open Access

Face-to-face vs. blended learning in higher education: a quantitative analysis of biological science student outcomes

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Abstract

The COVID-19 pandemic caused a rapid seismic shift to online delivery in otherwise face-to-face higher education settings worldwide. This quantitative research study sought to investigate the effect of different delivery styles and assessment types on student outcomes. Specifically, grades achieved by first year undergraduate Biological Science students at a UK Higher Education institution were compared from seven modules across two different academic years, namely 2018–2019 and 2020–2021. The academic year 2018–2019 was delivered in the traditional face-to-face manner whereas the 2020–2021 method of delivery was via blended learning. The results showed that four of the seven modules were negatively affected by the transition from face-to-face to blended delivery ($p < 0.05$, T-test). One module was unaffected ($p > 0.05$, T-test) and the remaining two modules were positively affected ($p < 0.05$, T-test). However, the percentage of students requiring reassessments increased with blended learning delivery although this was not significant ($p < 0.05$, T-test). In summary, the majority of individual module marks decreased with blended learning compared to face-to-face delivery, with an associated increase in required reassessments. Although there are positive benefits to incorporating an element of online learning for students, it is important to utilise this information in future module delivery planning to support the varying student cohorts of the future.

Keywords: Face-to-face, Blended online learning, Higher education, Teaching, Assessment

Introduction and literature review

The COVID-19 pandemic caused significant and far-reaching changes across Higher Education in the United Kingdom, fundamentally altering the academic landscape. The most immediate and visible change was the rapid shift to online learning as universities closed their physical campuses and transitioned to virtual classrooms. This sudden change to digital delivery required the adoption and integration of new technologies and teaching methods, presenting both opportunities and challenges for educators and students. While the pandemic-driven shift to online learning in the UK Higher Education sector was a rapid response to unprecedented circumstances, it also reignited and added

new dimensions to the ongoing discussion about the efficacy of face-to-face (F2F) versus online learning methods.

The debate about the benefits of F2F vs. online/remote/virtual learning has been long-standing with a wealth of literature in support of both modes of delivery at higher education level (e.g. Avella et al., 2016; Imel, 2002; Kemp & Grieve, 2014). Following the launch of the World Wide Web in 1991 the first learning management systems were developed enabling the introduction of online learning environments; with the first fully online courses appearing in 1995 (Bates, 2014). Virtual online learning provided a platform to access education remotely thus enabling students to access higher education where previously this would not have been a valid option. Personal circumstances for the inability to access F2F education include, but are not limited to, caring or parental responsibilities, challenges with physical or mental health, the requirement for paid daytime jobs and travel restrictions. Although the immediate positives of remote learning are obvious for the delivery of theoretical content over a flexible timescale, there are clear disadvantages including the dependence on self-discipline and self-motivation, social isolation and lack of engagement, limited educator-student interaction and feedback (Baltà-Salvador et al., 2021; Dumford and Miller, 2018; Jacob and Radhai, 2016).

Remote learning also poses significant additional challenges for practical courses where a key component involves hands-on practical experience (Bashir et al., 2021; Biel and Brame, 2016; Hallyburton and Lunsford, 2013). Losing this component reduces the skillset acquired during the course and therefore has downstream implications on future employment opportunities. Biological Science courses are an example, where the practical and theoretical content are interweaved throughout the course, providing students with a broad range of skills to increase their future outcomes.

The effect of the COVID-19 pandemic on delivery type

The most profound shift in pedagogical methods in education history occurred in the past 3 years due to the COVID-19 pandemic (Dhawan, 2020; Mali and Lim, 2021; Mpungose, 2020; Paudel, 2021). It disrupted over 1.7 billion learners in more than 200 countries (United-Nations, 2020), forcing rapid changes in digital practices and curriculum design to enable quality education (teaching, learning and assessment) to be delivered on the virtual domain. This exemplified weaknesses such as lack of online teaching infrastructure, limited exposure of educators to online teaching, the information gap, non-conducive environment for learning at home, equity and academic excellence in terms of higher education (Pokhrel and Chhetri, 2021).

The effect of the transition from F2F to online learning has had varying effects on student outcomes across higher education institutions both pre- and post-COVID-19 pandemic. A large study undertaken by Russell and the International Distance Education Certificate Center (IDECC) collated over 350 studies comparing F2F learning with online/remote learning and found that neither delivery method was significantly beneficial or detrimental to student outcomes (Russell, 1999). This finding was also supported by other studies from other higher education institutions, where no significant difference was found between online and F2F learning (Cavanaugh and Jacquemin, 2015; Driscoll et al., 2012; Paul & Jefferson, 2019). This was consistent with the literature collated in the 'no significant difference' database of 2004 (http://nosignificantdifference.

org/). More recently a study reported that economics students in South Africa achieved lower academic performance when studying remotely, with the main contributing factor being poor internet access (Chisadza et al., 2021).

Blended learning as a hybrid delivery method

Blended learning (BL) refers to the combination of pedagogic approaches; mixing technology-enhanced learning with more traditional, classroom-based, learning experiences (Bliuc et al., 2007; Bryan and Volchenkova, 2016; Nguyen, 2015; Oliver and Trigwell, 2005). It offers a hybrid learning programme through combining the advantages of online learning (e.g. often a more flexible schedule, student inclusivity) with the advantages of F2F learning (e.g. increased communication and interaction within the student cohort, between students and teachers, and increased potential for verbal feedback). There was a clear preference for blended learning over sole online learning in sports and exercise science students, with students appreciating the opportunity to meet F2F (Finlay et al., 2022).

Although most UK Higher Education delivery transitioned online during the COVID-19 pandemic-associated lockdowns, a blended learning approach was soon adopted across most of these institutions, and has continued to remain part of the present delivery method (Finlay et al., 2022). At the UK Higher Education institution in this study, a BL approach was implemented for Biological Science students in the academic year 2020–2021, combining traditional F2F learning, socially distanced laboratory practical sessions and remote, online, delivery. The department adopted strategies and technologies including virtual laboratories, and interactive online platforms to supplement the physical laboratory practical sessions. This approach provided students with up to 6 h of contact time on campus per week which included, but was not limited to, lectures, laboratory practicals and tutorials. The content of the modules remained unchanged where possible although, due to social distancing guidelines, group work in laboratory practical sessions was limited. The material during all the campus-based sessions could also be accessed virtually to ensure the inclusion of students learning remotely. All material (when delivered F2F and live online) was recorded allowing accessibility to students at times other than during the live delivery. This afforded students the flexibility required to adapt to home-schooling, part-time jobs and family commitments. But it also required the rapid learning of new technological platforms, for both teaching staff and students, and ensuring that the virtual learning environments were freely accessible to learners. Interactive, student-focussed online methods were included to encourage active engagement, with a greater focus on theoretical knowledge and virtual practical experiences, balancing the reduced opportunity for hands-on laboratory work.

Assessment strategies

In conjunction with the change in teaching delivery came the potential requirement for change in assessment type (Bashir et al., 2021; Benson and Brack, 2010). In-house examinations changed to online, open-book, assessments and face-to-face oral and poster presentations moved to an online platform. At the higher education institution in the present study, assessments remained the same in the BL year than they were for the F2F year for the first-year modules, but both the written exams (time-limited

assessments) and oral presentations moved to an online format. Formative assessments also gained prominence, providing ongoing feedback in the absence of regular in-person interactions.

Aims of the study

The aim of this study was to critically analyse the marks obtained by first year undergraduate Biological Science students at a UK Higher Education institution in a normal F2F teaching year (2018–2019) and a BL teaching year due to the COVID-19 pandemic (2020–2021).

The ultimate objective of the study was to use the results obtained to inform future practice on delivery method and assessment types for enhancing students' outcomes.

Research questions

- Did the learning environment (F2F vs. BL) affect marks from first year undergraduate Biological Science students?
- Did assessment type affect student outcomes in individual modules?
- Did the transition from F2F to BL delivery influence the frequency of students requiring reassessments, and was there a noticeable difference between genders in the proportion of first sitting failures?

This is a timely study in the context of the ongoing need for students to access higher education both F2F and remotely.

Methodology and methods

Experimental design

End-of-module marks from first year undergraduate Biological Science students from the academic years 2018–2019 and 2020–2021 were collected and analysed. These academic years were selected due to their different modes of delivery; 2018–2019 purely F2F teaching vs. 2020–2021 blended teaching due to the COVID-19 pandemic (BL in this context being up to 6 h per week F2F teaching and the remainder delivered online). First year students were selected as they had no previous experience of higher education Biological Science teaching, learning and assessment, therefore they had only experienced a single delivery type (F2F or BL) at the time of taking their first-year assessments.

Data were collected across all the Biological Science degree programmes available (BSc (Hons) Biology, BSc (Hons) Biomedical Sciences, BSc (Hons) Biotechnology, BSc (Hons) Ecology and Conservation, BSc (Hons) Plant Sciences). Data comprised of marks (anonymised) from each student over the seven first year modules (Ecology, Biodiversity, Biology in Practice [BinP], Chemistry for Biologists [CforB], Introduction to Cell Biology [ICB], Anatomy and Physiology [A&P] and Genetics and Evolution [G&E]). 92 students were enrolled in year 2018–2019 and 103 students were enrolled in year 2020–2021. Marks were collated from first sittings and from final sittings (if reassessments were required, with reassessment marks capped at 40%). Information on the assessment types for each module for each of the two years in the study was accessed from archived module handbooks. A comparison between the assessment types was analysed.

Sampling strategy

All students registered as a first-year student on a Biological Science degree course at the selected UK Higher Education Institution in the years 2018–2019 and 2020–2021 (who undertook the assessments) were included in the study regardless of age/gender/background. Therefore, bias was eliminated due to lack of selection of students. Gender was determined as the assigned gender with which a student had registered on the course.

Students from both cohorts were given the opportunity to hire digital equipment and to attend courses (in person and virtual) to enhance their use of digital technology. This was particularly relevant to the BL cohort.

Use of student grades

Student mark data is available to authorised staff within the University and is owned by the University. No burden was put on the students to provide information for the study. Raw mark data was anonymised by removal of student names and numbers, therefore the identity of each individual student could not be ascertained. The list of marks per module was provided in a random order (not alphabetical) so to further maintain student anonymity. The large cohort size (>55 students per module, >90 students per year group) reduced the chance of identifying an individual student. The focus of this study was the trends in results in contrast to individual student outcomes. Anonymity of the data removed any downstream effect on the students during the rest of their degree program.

Data analysis

Data were collated in Microsoft Excel and subsequently analysed using GraphPad Prism. Marks per module were analysed as mean $\pm$ standard deviation. Raw mark data was tested for normality using the Kolmogorov–Smirnov test (if $n>50$) or Shapiro–Wilk test (if $n<50$). Comparison between the F2F and BL years was then statistically tested using Students' T-test (for normal data) or a Mann–Whitney U test (for non-normal data), where $p<0.05$ was considered statistically significant.

Ethics approval

Ethical approval was provided by the University PGCTHE Ethics Panel.

Results

Student metrics across F2F and BL years

Student module marks were collated and analysed from first year undergraduate students carrying out Biological Science degrees at a UK University from the academic years 2018–2019, when students received F2F delivery, and 2020–2021, when students received BL delivery. Changes to module titles had occurred over the period of the study, but the content and assessment types remained the same (Table 1). The change in module titles occurred prior to, and was therefore unrelated to, the onset of the pandemic.

The number of students increased from 92 students in 2018–2019, reaching an intake of over one hundred students across five Biological Science programmes in 2020–2021. This increase was reflected across the compulsory and elective modules (Fig. 1). There

Table 1 First year undergraduate biological science module titles and assessment types for the 2 years of study; 2018–2019 (F2F) and 2020–2021 (BL)

2018–2019 module title (F2F)	2018–2019 assessment types	2020–2021 module title (BL)	2020–2021 assessment types	Compulsory or elective module
Biology in practice	30% formal report	Biology in practice	30% formal report	Compulsory
	45% oral presentation		45% oral presentation	
	25% reflective report		25% reflective report	
Cellular form and function	50% MCQ	Introduction to cell biology	50% MCQ	Compulsory
	50% practical		50% practical	
Variation, evolution, heredity	60% essay	Genetics and evolution	60% essay	Compulsory
	40% written exam		40% written exam	
Biodiversity	50% MCQ	Biodiversity	50% MCQ	Elective
	50% practical assessment		50% practical assessment	
Chemistry for biologists	50% scientific report	Chemistry for biologists	50% scientific report	Elective
	50% written exam		50% written exam	
Ecology	50% data retrieval test	Ecology	50% data retrieval test	Elective
	50% poster presentation		50% poster presentation	
Human body systems	50% data retrieval test	Anatomy and physiology	50% data retrieval test	Elective
	50% written exam		50% written exam	

Module type (compulsory or elective) is stated

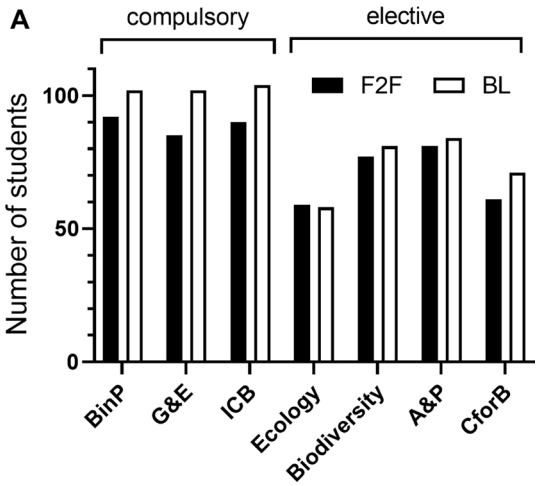

Fig. 1 Analysis of student metrics. Number of students taking each of the seven modules in the F2F learning year 2018–2019 and the BL year 2020–2021

was an increase in the number of students undergoing reassessment module assessments in the BL year when compared to the F2F year in six of the seven modules (Fig. 2A; 9.1% of students in the BL year underwent reassessments compared to 5.7% of students in the F2F year). Although pronounced, this increase was not significant ($p > 0.05$, T-test).

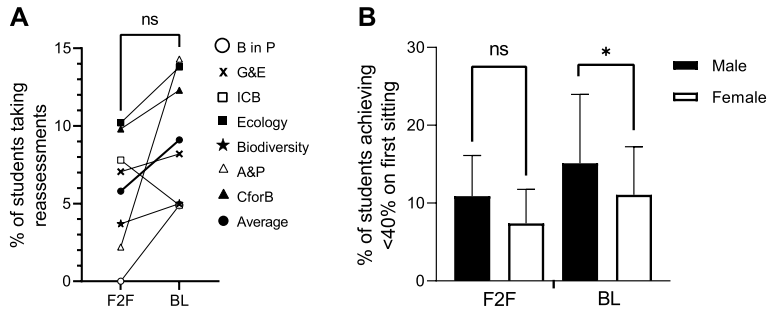

Fig. 2 Effect of delivery type on students requiring reassessments. **A** Percentage of students taking reassessments on each of the individual modules in the F2F and BL years. Modules are represented by different symbols as shown in the legend. The average is shown. **B** Percentage of students achieving less than 40% in first sitting module marks, separated by delivery type and gender. Bars represent mean and standard deviation across the seven modules. * represents $p < 0.05$; ns denotes not significant, $p > 0.05$; T-test

Table 2 Average final sitting module marks across seven first year modules in the two years of study; 2018–2019 (F2F) and 2020–2021 (BL)

	Face-to-face learning (%)		Blended learning (%)		P value	Signif.	
	Mean	SD	Mean	SD			
Biology in practice	62.3	8.9	58.3	13.1	0.0156	*	↓
Genetics and evolution	56.5	14.2	51.2	12.8	0.0079	***	↓
Introduction to cell biology	65.1	11.4	68.7	11.8	0.036	*	↑
Ecology	51.9	9.3	54.8	14.7	0.064	ns	
Biodiversity	53.5	13.2	62.5	14.5	< 0.0001	***	↑
Anatomy and physiology	55.5	14.6	50.8	13.6	0.038	*	↓
Chemistry for biologists	59.2	17.5	53.3	10.3	0.0199	*	↓

Data are mean ± standard deviation. *$p < 0.05$, ***$p < 0.01$, ns denotes not significant; T-test. Arrows denote a significant increase or decrease in BL marks compared to F2F marks

For each module, the percentage of students achieving less than 40% for the first attempt was calculated and then this was averaged across the seven modules. This was then further separated by the registered gender of the students. This analysis was performed to determine whether there was a gender-related difference in failure rate (Fig. 2B). An increase in failure rate was observed in the BL year compared to the F2F year for both genders (Fig. 2B). In the F2F year, there was no significant difference in the percentage of male and female students achieving less than 40% in the first sitting module marks ($p > 0.05$; T-test). In contrast, significantly more male students achieved less than 40% in the first sitting module marks compared to female students when BL was delivered ($p < 0.05$; T-test; Fig. 2B).

Analysis of module marks across varying delivery years

Final module marks were analysed across the F2F and BL years (Table 2 and Fig. 3A–G). Marks significantly decreased in the BL year compared to the F2F year in four modules: BinP, G&E, A&P and CforB (Table 2 and Fig. 3A, B, F, G; $p < 0.05$, unpaired T-test). The marks for the Ecology module did not significantly change over the two years of study (Table 2 and Fig. 3D; $p > 0.05$, unpaired T-test). Interestingly, the marks for two modules,

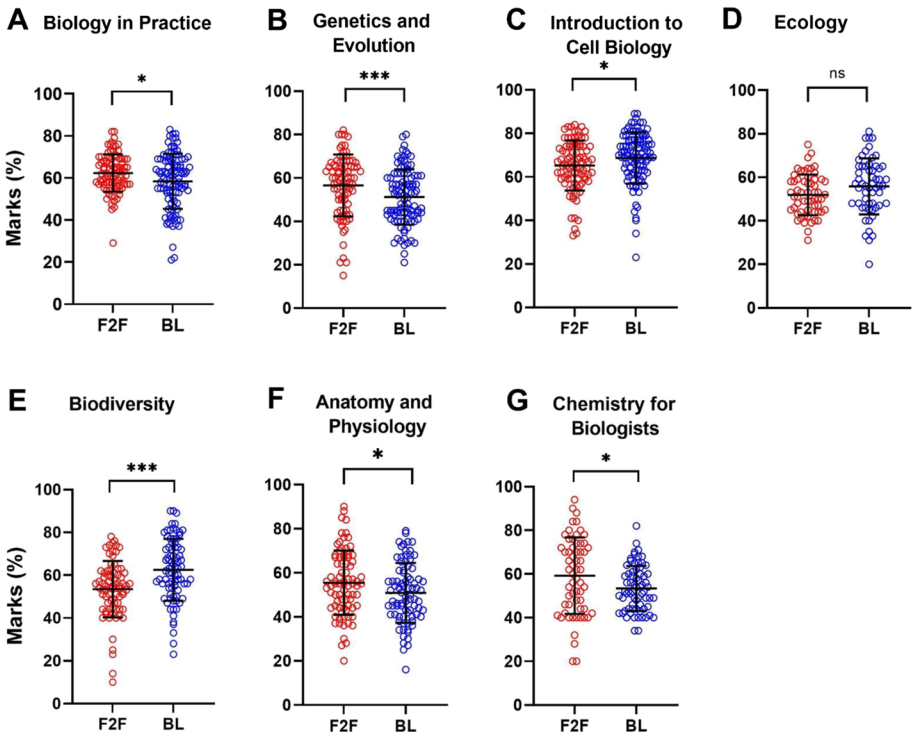

Fig. 3 Analysis of final sitting student marks across delivery types. **A**–**G** Final module marks for each of the seven modules in the F2F and BL years. Each individual student mark is represented with a datapoint on each graph. Bars show mean ± SD for all students taking the assessments. ns denotes not significant, *represents $p < 0.05$, *** represents $p < 0.01$; T-test)

ICB and Biodiversity, significantly increased in the BL year vs. F2F year (Table 2 and Fig. 3C, E; $p < 0.05$, unpaired T-test).

Final sitting marks were further separated by students' registered gender to determine whether the change in delivery type had a gender-specific effect on module mark outcomes (Fig. 4). The marks of both the female and male students reflected those of the whole student cohort (shown in Fig. 3), where there was a decrease in average modules marks in BinP, G&E, A&P and CforB. But the decrease in marks for these four modules in BL vs. F2F delivery was greater in the female student cohort than those from male students (Fig. 4A, B). Increases in average module marks were observed in the remaining three modules from both female and male students. Interestingly, the average female student module mark decreased across the F2F and BL years (F2F: 58 ± 8% compared to BL: 57 ± 7%; Fig. 4A) whereas the average male student module mark increased across delivery type (F2F: 54 ± 1% compared to BL: 55 ± 0%; Fig. 4B), although both results did not differ significantly ($p > 0.05$, T-test).

Effect of assessment type on student outcomes across varying delivery methods

To assess whether assessment type was a factor in student mark outcomes, modules were separated based on their particular types of summative assessments; written exams (which comprised of time-limited assessment), practical assessment and presentation assessment (which comprised poster or oral presentations) (Fig. 5). The modules with

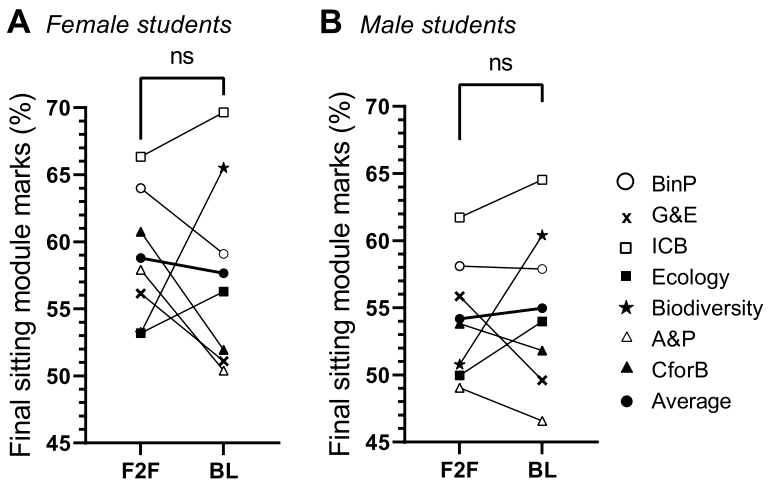

Fig. 4 Final module marks separated by gender. Graphs showing average module marks achieved by (**A**) female students and (**B**) male students in the F2F and BL years. Modules are represented by different symbols as shown in the legend. The average is shown. *ns* not significant; T-test

a summative written exam showed significantly lower end-of-module marks in the BL year when compared to the F2F year (Fig. 5A; $p < 0.05$; T-test). In contrast, the modules with a summative multiple-choice question (MCQ) assessment showed elevated marks in the BL year (Fig. 5B; statistics not performed due to $n < 3$). This goes some way towards explaining why the ICB and Biodiversity module marks benefitted during BL delivery (Table 2 and Fig. 3C, E respectively) as 50% of their overall module mark was from the MCQ assessment. An increase in modules marks was measured in the BL year when modules were separated by inclusion of a practical assessment (Fig. 5C; statistics not performed due to $n < 3$). In contrast, modules without a practical assessment fared badly in the BL year compared to the F2F year, although this was not significant (Fig. 5D; $p > 0.05$; T-test). Interestingly, inclusion of a presentation assessment (poster or oral) failed to affect the module marks across the contrasting delivery years (Fig. 5E, F; $p > 0.05$; T-test).

Discussion

This study aimed to analyse, in detail, the effect of two contrasting delivery methods, F2F vs BL, on first year undergraduate Biological Science student marks at a UK Higher Education institution. A wealth of data were included for analysis from > 90 students per year, across seven modules.

The results found that the proportion of students taking reassessments increased in the BL vs. F2F year although this increase was not statistically significant (Fig. 2). It is noteworthy to suggest that this correlates with studies showing that students have an increased positive perception of F2F learning (Nasution et al., 2021), with F2F learning enabling communication and interaction within the student cohort and between students and teachers (Paechter & Maier, 2010). A significant skew towards males achieving less than 40% in the first sitting of modules in the BL year (Fig. 2) may suggest that this gender benefit more from F2F learning and the interaction that this provides. This supports other research where males struggled more with the shift

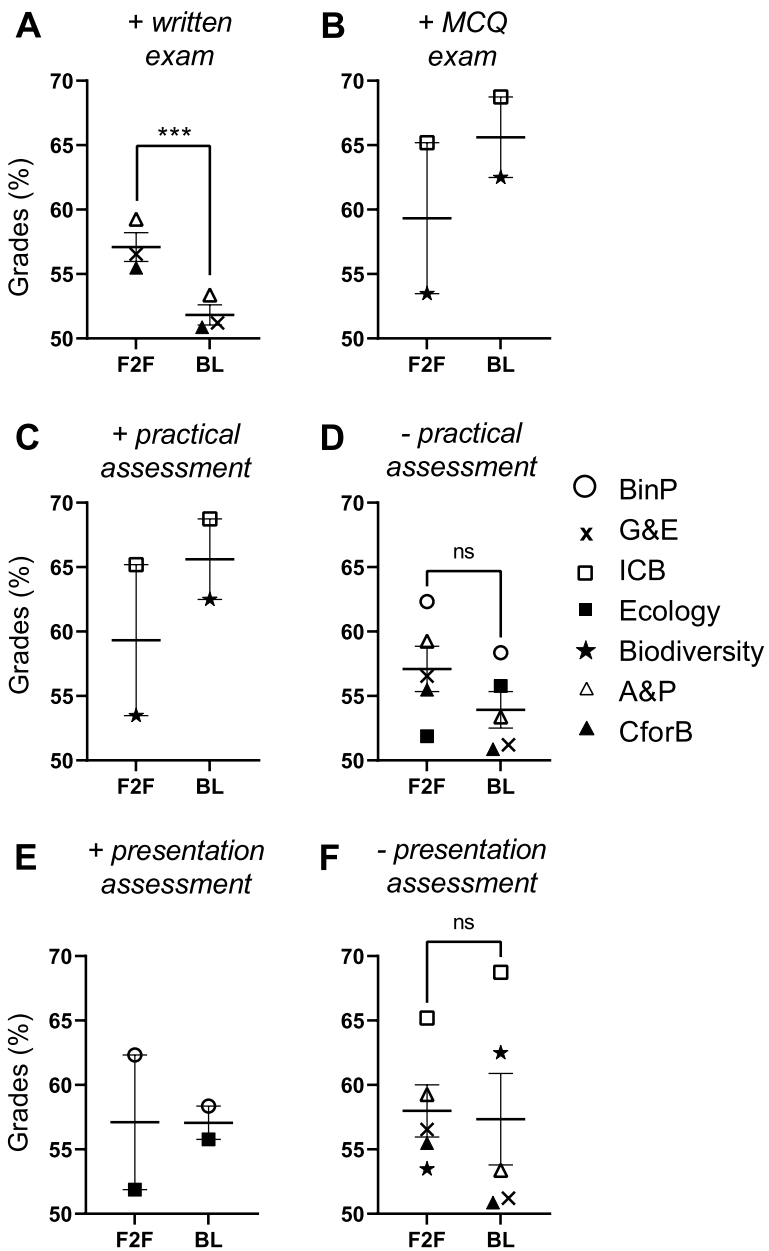

Fig. 5 Effect of assessment type on mark outcomes. Analysis of final module marks in F2F compared to BL years in modules with a summative written exam (**A**), summative MCQ (**B**), including a practical assessment (**C**), without a practical assessment (**D**), including a presentation assessment (**E**), or without a presentation assessment (**F**). Data represents average module marks. Bars represent mean ± SD. Significance is determined by T-test (where ns denotes not significant, *$p < 0.05$, ***$p < 0.01$). Modules are represented by different symbols as shown in the legend

to online learning in the COVID-19 pandemic (Chisadza et al., 2021; Yu, 2021), with female students achieving significantly higher outcomes in online learning (Alghamdi et al., 2020) or self-regulated learning (Caprara et al., 2008; Pajares & Valiante, 2001) than male students. If an element of online learning is to remain part of future course planning it is imperative to ensure that all students receive training on the virtual

platform in advance, as well as having the option to loan a device from the University. This would negate the possibility of excluding students due to not being able to use the software or having access to a usable device.

Although the aforementioned results showed that significantly more male students were graded under 40% in the first sitting module marks than female students during BL (Fig. 2B), the average final module mark from male students was unaffected between the two delivery styles and even showed a slight increase during BL delivery (Fig. 4B). In contrast the average final module marks from female students showed a decrease in the BL year when compared to the F2F year, although not significant (Fig. 4A). This potentially implies that although male students were possibly slower to adjust to the change in delivery type (causing an increase in marks below 40% in the first sitting), the BL delivery did not significantly disadvantage their overall outcomes.

The spread of student marks often approaches a normal distribution if a large sample size is used (Akella et al., 2017; Ho et al., 1981; Lyon, 2020), with the majority of students clustered around the middle grades. The data can become skewed following reassessments due to these marks being capped at 40%. Interestingly there appeared to be an increase in the spread of the marks in the BL delivery year compared to the F2F delivery year across the modules (Fig. 3). This change in the spread of the data can be suggestive of underlying factors other than just student variation. In the BL year there were also factors that would differentiate students on their ability to achieve their highest potential. These include, but are not limited to, access to technology, access to adequate internet connection, other responsibilities (e.g. childcare/home-schooling), engagement during the sessions and inability to work at a screen for continuous periods. Due to the speed of the transition to online learning at the beginning of the pandemic these factors were not addressed as effectively as they could otherwise have been. But, if the online platform is going to be, at least in part, continued then the University has a responsibility to ensure that students have the access to equipment that is required.

Separating module grades by assessment type provided a useful indication of whether certain assessments were beneficial or disadvantageous to BL environments. Modules incorporating a summative written exam showed significantly decreased marks in the BL year compared to the F2F year (Fig. 5A). This potentially suggests that the in-depth understanding of the subjects was not attained as efficiently following online delivery. Hence it could be speculated that students felt less forthcoming in asking questions when delivery was online. In contrast, the modules that included a 50% summative MCQ assessment generated higher overall marks in the BL year compared to the F2F year (Fig. 5B). One possible reason for this could be that, due to these assessments taking place remotely, students were afforded unrestricted access to teaching materials and external source materials.

Interestingly, the literature reports that males outperform female on multiple choice assessments, with female students achieving higher marks in longer answer tests (Reardon et al., 2018), although this study was based on high school aged students. The results in this present study suggest that both males and females at higher education level benefit from MCQ assessments as average module marks increased for both genders in the BL vs. F2F years in the modules that included a 50% summative MCQ assessment (Fig. 4A, B; ICB and Biodiversity modules).

Although BL delivery did enable some F2F contact (up to 6 h per student per week for the students in the present study), it has been reported in the literature that the COVID-19 restrictions affected learning efficacy even within F2F practical classes, with reduced student numbers in large spaces and the need for social distancing causing awkwardness and fewer peer-to-peer interactions (Khan et al., 2021). The results in the present study show that module marks in modules containing a practical assessment (Biodiversity and CforB; Table 1) were increased in the BL year compared to the F2F year in contrast to modules without a practical assessment (Fig. 5C, D). This would suggest that the students in the present study benefitted from the opportunity to continue their practical work to provide interaction between their peers as a contrast to independent, self-directed study. Practical work is a significant component of Biological Science courses, but this highlights the importance of maintaining and developing opportunities for group working to maximise student interaction and communication within modules.

Marks across the F2F and BL years were not significantly affected by the incorporation of a presentation assessment (poster or oral presentation; Fig. 5E, F), although several students expressed a preference and also relief in presenting online rather than in person (Katy Andrews, *personal communication*). This reflects a lack of confidence in the student cohort, likely due to missing out on the vital interaction that occurs at the beginning of the first year at university. It is important to ensure that confidence in presenting to an audience is developed throughout the course as this is a key skill for future employability. Therefore, the incorporation of small-group presentations (both online and F2F) should be included in future module development for students to gain maximal experience.

Informing future practice

Even though the COVID-19 restrictions are now lifted in the UK, and F2F learning has primarily been resumed, the positive role that remote learning can play has been widely recognised and will likely remain to have some role in higher education teaching henceforth. There are lessons to be learnt from the rapid monumental shift to online learning in March 2020 that will be used to shape future module planning and delivery (Nerantzi, 2020). A key benefit of online delivery is the ability to access the content asynchronously, where the students are able to access pre-recorded material at their own pace (Lapitan Jr et al., 2021) and around personal commitments. But there is also a place for synchronous online teaching, where students access the online classroom live. The results of the present study concur with a wealth of literature demonstrating that, when online teaching is incorporated into a curriculum, emphasis must be placed upon maintaining interaction within the students and between students and the teacher (Finlay et al., 2022; Lapitan Jr et al., 2021; Maatuk et al., 2022; Mali & Lim, 2021; Paechter & Maier, 2010; Vo et al., 2020). This includesd the inclusion of breakout groups (thus providing a small-group environment to enable communication), quizzes and interactive activities, and sharing work within the virtual learning environment to encourage discussion and feedback. There are advantages to offering students the option of choosing online student–teacher meetings over F2F, for example when discussing draft feedback on formative assessments. This could reduce unnecessary travel to campus. This will continue to be offered as an option

for students if they express this preference. The time of day and frequency of delivery method has also been found to be important, with F2F learning preferred when courses were offered in the late morning or early afternoon (Paul & Jefferson, 2019). Therefore, if online learning is to be included in future module delivery it could be most advantageous for morning teaching sessions.

The opinions of students on their perceptions of F2F and BL is beyond the research in the present study but would be interesting to pursue further to understand the underlying reasons involved, for example whether motivation and engagement are compounding factors. Personal communication with students suggested that there were mixed opinions regarding preferences for F2F and BL. But the importance of student interaction was highlighted, and indicated that, if online teaching is to remain an element within future course planning, it should be secondary to on-campus F2F delivery.

For future planning of assessment strategies, the results from this study show that maximal student outcomes are achieved when online delivery is assessed using MCQ tests although, with future assessments being held on campus, this result may change due to the restriction in access to external online material.

Considerations for the inclusion of online content in future module delivery

- Universal access to suitable devices: it is vital to ensure that all students have access to appropriate equipment and digital tools required. The University should actively signpost support services that can loan out such devices to the students who need them, ensuring equitable access to essential technology.
- Comprehensive pre-session training: Before the commencement of online delivery, detailed training sessions tailored to the Biological Science discipline, should be offered. These sessions should cover all aspects of digital literacy relevant to the tools that will be used on the modules.
- Interactive content in online sessions: Enhance online sessions with interactive content, including breakout rooms and peer review sessions. These activities encourage active engagement and collaboration through work in small groups.
- Use of digital assessments: For example, MCQ tests can be used as both formative feedback and summative assessment. Online practical quizzes that simulate laboratory scenarios could be used to compliment physical laboratory-based practical sessions.
- Flexible access to recorded content: Recording both F2F and online content enables students to access material at a convenient time. Recordings of laboratory demonstrations or scientific discussions would allow students who have valid absences to catch up effectively. Material should be easily accessible and organised to align with the module structure.

By tailoring these considerations to the nature of Biological Sciences modules, the inclusion of some element of online content in future module delivery can be optimised to enhance learning outcomes and ensure that all students have equitable access to education, regardless of their personal circumstances or learning preferences.

Limitations

This study investigating F2F and BL delivery in Higher Education, specifically on a Biological Science programme, revealed key insights and limitations that align closely with the ongoing debate about the effectiveness of different delivery styles.

The research compared first-year undergraduate marks from two different academic years where the delivery style differed (traditional F2F learning in 2019–2019 and BL in 2020–2021). The majority of modules showed a decrease in overall module mark with BL delivery, with one module unaffected and two modules showing improvements. The need for reassessments was increased (although not significantly) following BL delivery. However, the findings must be contextualised within the limitations of the study. Although the quantitative mark data was robust, mere statistical analysis fails to capture the differences caused by teaching methods within each delivery style. The study also does not account for complexities in assessment literacy. Understanding how students interpret and engage with different types of assessment is critical for a true evaluation but was beyond the objectives of the present study. The students selected were all first-year, enabling the assumption that this was the first University experience for the majority.

A notable omission is the measurement of student engagement, a key factor in learning effectiveness. This was not the focus of the study, which was to quantify student outcomes resulting from differing styles of delivery, but would be an interesting future avenue for research. The focus on a single subject area and institution are also limiting factors. Biological Sciences, with the blend of practical and theoretical content, may limit the generalisability of the study's findings, but sets a foundation for potentially comparing the effect to those of other subject areas. The impact of the pandemic also increased stress, mental health challenges and other external factors amongst students, which might have significantly affected the academic outcomes during this period.

Given the limitations discussed, it could be argued that relying solely on statistical tests on marks from differing student cohorts may not provide sufficient evidence to support changes in future practice. However, the present analyses do offer insight into the effect of delivery style on student outcomes and, when combined with other qualitative and pedagogical research, can inform future teaching methods and curriculum design.

Conclusion

Implications for practice and future research

The results of this timely study show that the effect of BL on student marks was module-specific, with students achieving significantly reduced marks in more than half of the modules in BL vs. F2F delivery. This was correlated with an increase in the proportion of students undergoing reassessments and an increase in first sitting failure (< 40%) rate. A greater proportion of male students failed on the first sitting but, interestingly, BL had a more pronounced negative effect on female students' overall module marks.

Therefore, although there are apparent benefits of online learning, e.g. enabling students with external commitments to engage with the course in their own time, thus supporting student inclusivity and engagement, it is important to ensure that appropriate training and access to the technology is provided to students in advance. To ensure that

this occurs, slides should be included in lecture material to signpost the support services available to students and this should be reiterated in tutorial sessions. With these measures in place, maintaining an element of online learning within the predominantly F2F curriculum should not be detrimental to overall student outcomes.

Future directions of this work would be to correlate student outcomes with information on student perceptions of F2F vs. BL. This would provide valuable insight so that emphasis is placed on the optimal delivery methods, teaching quality and assessments to inform future course planning and ensure that the students are provided with the optimal environment to achieve their greatest potential.

Acknowledgements
The authors thank Professor Paul Ashton and Katy Andrews for discussions on the results of the study.

Author contributions
CVH designed the study, analysed the data and wrote the manuscript. LMM collated the data and advised on the manuscript. LM was involved in critical discussions of the work and assisted with writing the manuscript.

Funding
Not applicable.

Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests
Not applicable.

Received: 17 August 2023 Accepted: 12 December 2023
Published online: 10 January 2024

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