What is known in literature about online exams in higher education in general, and in particular in Physics and Maths?

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Abstract

When the Covid pandemic affected education, universities around the globe had to move not only their content delivery online, but also their assessments. Besides the fact that Covid caused significant upheaval in HE, this enforced experiment also afforded an opportunity to reflect on traditional, invigilated, closed book exams (ICBE) resulting in research and advice in this area. A systematic review of this academic and grey literature was performed concentrating on maths heavy physics examinations to investigate what guidance is given to exam writers, educators who prepare students for exams and HE examinees themselves.

The literature review results were divided into: Advice for examiners who need to provide an uninvigilated, open book exam (UOBE), discussions on cheating, advice for students and case studies. It was found that ICBEs were good at examining lower order cognitive skills, e.g. recall and understanding, but higher order skills, such as analysing and synthesising, are better examined with access to a larger range of resources. Guidance on making academic misconduct more difficult also suggested using higher order thinking skills in exam questions as responses to this type of tasks are more individual and getting outside help may be more difficult in a time constrained UOBE. Furthermore, literature encouraged reflection on the motivation for cheating and suggested that overly demanding assessment may encourage students to seek inappropriate help. The advice for students highlighted the need to prepare as thoroughly for a UOBE as they would for a traditional exam. Probably the thrust should change from pure memorization to students preparing their notes so that they can efficiently access their material to locate relevant parts for synthesis during a UOBE. Some of the case studies used statistical methods to investigate comparability of grades between UOBEs and ICBEs and some of the studies found them comparable, so a large shift of results may be due to other factors rather than the exam type. Other studies describe their approach and included stakeholder reflections.

The main recommendation to not use lower cognitive skills can pose a problem for maths heavy exams as they mainly assess how well an examinee has mastered these skills before building on them. However, it seems advisable to climb higher up Bloom's taxonomy if at all possible. Also, it may be conceivable to break up exams into shorter sections that require individual uploading before access to the next part is granted to reduce the possibility of outside help. Furthermore individualised maths type problems could be achievable by using different data sets for a question. Student advice should highlight the differences between UOBEs and ICBEs so that they can prepare appropriately.

Keywords: Open book exam; closed book exam; physics; maths; exam preparation

Introduction

There was some interest in re-evaluating the assessment in higher education even before Covid caused a lot of upheaval in the educational sector (Ball *et al*, 2012), but it was the response to this pandemic that required HE institutions around the world to discontinue traditional, in-person exams and rely on different ways to assess student learning (Babbar and Gupta, 2021). Although this may

be described as an unwanted experiment, some in the academic community have further advocated reflecting on the merits on the ICBE format and to explore different assessment methods. (Hobson, 2022; Sambell and Brown, 2020). However, the adoption of alternatives, such as uninvigilated, online time constrained assessment, has raised concerns about academic misconduct (QAA, 2020), which may impact on degree accreditation requirements. The Institute of Physics (2022), for instance, requires a robust quality assurance so that appropriate quality and standards are maintained . With the rise of contract cheating, it could be argued that it is harder to ensure that UOBEs guarantee that the work submitted is really that of a particular student (QAA, 2022).

As the issues alluded to above relate also to fields other than physics, it is not surprising to find systematic literature reviews covering other academic areas (Johanns *et al*, 2017; Durning *et al*, 2016) or specific alternatives, e.g. take-home exams (Bengtsson, 2019). This review, on the other hand, aims at maths heavy physics UOBEs and includes expert advice found in grey literature to answer the question: What does the literature say about how to set and prepare for UOBEs in higher education in general, and in particular in physics and maths?

Methodology

To aid the execution of this literature search a review protocol (Booth *et al*, 2016) was prepared, thus following the approach taken by Bengtsson (2019) ,and Babbar and Gupta (2021) who reviewed literature in related areas. However, when executing the search strategy, it became apparent that the search terms used in Google Scholar (notably only including 'maths' and 'physics') were too narrow and other allied academic fields were included to give a more comprehensive view of academic literature. A similar modification had to be made for the generic Google search engine to find associated grey literature. The search terms which seemed to yield the most appropriate results were:

- Google scholar: allintitle: (exam OR exams OR examination) (Engineering OR Science OR STEM) online: About 47 results (some papers may have been listed twice)
- Google: allintitle: Covid (exam OR exams OR examination) site:ac.uk: 142 results
- Google: allintitle: Covid (exam OR exams OR examination) blog: 110 results

After screening these results, relevant documents were downloaded and divided as shown in Table 1. Although there may be a certain overlap in the documents, e.g. the case studies may relate to either one or more of the other categories, these headings are also used when presenting the results for convenience. Documents classed as 'academic' refer to journal articles and conference presentations, whereas grey literature included expert advice or university guidance documents.

Table 1: Breakdown of downloaded documents

Category	Academic	Grey
Advice for examiners on online exams and alternatives	2	7
Cheating	6	5
Advice on student wellbeing and exam preparation	7	5
Case studies	13	

As the major interest of this study lies in online examination which closely resemble closed book invigilated exams, multiple choice quizzes are not focused on (although this is a popular online exam format) for the majority of the results sections. However, case studies the comparability between online and in-person exams using multiple choice were included.

Results

Advice for examiners on online exams and alternatives

Some of the documents reviewed discuss the merits of traditional ICBE such as reducing the risk of academic misconduct (Bengtsson, 2019; Brown and Sambell, 2020b), increasing fairness as all candidates are under the same exam conditions (Heriot Watt University, 2020) and general acceptance by society and accreditation providers as a candidate's own performance (Sambell *et al*, n. d.). Bengtsson (2019) also reports on possible drawbacks of UOBEs e.g. promoting lower level of learning or lower academic achievement. Furthermore, Babbar and Gupta (2021) highlight the danger of academic dishonesty for online exams pointing to reports of surges of exam related Google searches during the actual exam. Having said that, the demerits of closed book exams are probably more clearly articulated in the literature and include examination of lower order thinking skills only (Heriot Watt University, n. d.-a), the problem with examining all learning outcomes in one piece of assessment (Bengtsson, 2019), giving only a performance snapshot during a busy exam period or the opportunity for only limited assessment authenticity (Sambell and Brown, 2020). Regarding online examination the following points were advised:

- **Question design**: Start with considering the learning outcomes (Brown and Sambell, 2020c; Heriot Watt University, n. d.-c; Heriot Watt University, n. d.-b), do not rely only on lower order thinking skills (i.e. recall and understanding), but also include application, interpretation and analysis (Brown and Sambell, 2020b; Sambell *et al*, n. d.). Start with questions about basic facts (Gordon, 2020) and distribute marks accordingly (Heriot Watt University, n. d.-c). Consider 'real life', authentic examples. Make question student specific (Heriot Watt University, n. d.-a). Ask for proof and justification of all answers. Randomise question sequence (Bengtsson, 2019).

- **Time limits**: Be careful to set appropriate, stringent time limits as students may think that a 24 h exam means to work on it for 24 hours (Brown and Sambell, 2020b; Sambell and Brown, 2020).

- **Academic misconduct**: Print exam with watermark and disallow printing or downloading. Introduce honour code. Ask for handwritten answers (Bengtsson, 2019). Announce random virtual vivas to be conducted after the exam (Brown and Sambell, 2020b; Heriot Watt University, n. d.-c). Hire invigilation service (Brown and Sambell, 2020a; Bengtsson, 2019) or monitoring a student's workplace (Babbar and Gupta, 2021).

- **Student briefing:** Emphasise the need for exam preparation (Brown and Sambell, 2020b), such as memorizing material and prepare potential answers (Gordon, 2020). Explain the need for referencing (Brown and Sambell, 2020b). Encourage students to practice writing under tight time conditions (Sambell and Brown, 2020). Brief on academic misconduct policy (Brown and Sambell, 2020b).

- **Exam system**: Stress test the exam system and make allowances for technical issues (e.g. internet problems) (Brown and Sambell, 2020b).

- **Invigilator**: Provide a virtual invigilator in a supportive role as emergency contact for students (Brown and Sambell).

Cheating

Before looking at some practical advice on discouraging cheating it may be beneficial to understand why academic misconduct occurs. For cheating to occur two main factors have to coincide: Motivation and opportunity (QAA, 2022). Some factors that can provide encouragement to deliberately engage in academic misconduct could be external. For instance, Abdelrahim (2021)

reported that the fear amongst Bangladeshi students that they themselves or a family member could contract Covid or that mental health related effects of quarantining made cheating more likely, and in a newspaper article, Akhabau (2021) also reported that STEM students cheated more during the pandemic. Other external factors may be related to a lack of understanding (especially if English is not an examinee's first language), the assessment design, dissatisfaction with the teaching approach and pressures from family and/or job related demands (e.g. the requirement to pass the exam to practice a certain occupation) (Sambell *et al*, n. d.; QAA, 2022; Morales-Martinez *et al*, 2019). The literature also refers to internal factors, such as "pure laziness" (Sambell *et al*, n. d., p 1), social acceptance of cheating (Georgescu and Berechet, 2022), poor time management (QAA, 2022) or suggests that it is in human nature to do so (Georgescu and Berechet, 2022).

Regarding opportunity, Manteufel *et al* (2020) say in their conference paper in which they discuss engineering exams in the US (including invigilated exams): "Cheating on exams using an online tutor is simple." Up to recently, easy access to such services was also given as a reason for an increase in cheating in the UK (Sambell *et al*, n. d.; QAA, 2022), but in April 2022 the Skills Minister Alex Burghart (2022) wrote to internet service platforms, frequently referred to as 'essay mills', to inform them that it is "a criminal offence to provide or arrange for another person to provide contract cheating services for financial gain to students taking a qualification at … a higher education provider in England." However, the advice provided by the QAA (2022) highlights that, although offering such a service is illegal, using it has not been criminalised.

Regarding online examination the included literature made the following points:

- **Identity checks**: Retain usual safeguards, such as checking student ID or logons (Lawrence, 2020) and use other means, e.g. handwriting, keystroke/mouse dynamics or fingerprint authentication (Al-Shalout *et al*, 2021).

- **Time limits**: Online cheating help is available on short notice, but it is harder to cheat on shorter exams and it is more noticeable (Manteufel *et al*, 2020; Sambell *et al*, n. d.). However, advice from QAA (2022) suggests that shortening deadline may increase the use of essay mills (although the guidance does not specify the assessment type).

- **Spread assessment tasks** over the whole module and between modules to reduce stress (Hendry, n. d.) and consider using regular low stake assessment (QAA, 2022).

- **Exam questions**: Do not use old exam questions or a question with a readily available solution (Manteufel *et al*, 2020). Use higher order cognitive skills (Hendry, n. d.; Lawrence, 2020). Change the task format (Hendry, n. d.).

- **Lack of supervision increases the likelihood to engage in academic malpractice** (Georgescu and Berechet, 2022; Morales-Martinez *et al*, 2019).

- **Cheating is possible whatever the safeguards are** (UNIwise, 2020; Manteufel *et al*, 2020), therefore make resources available to detect cheating. Detection mechanism (informed by grade shift) could use a viva after the exam, activity search online (essay mills outsource, so a simple online search could yield appropriate results). Specific training should be given to academic staff (QAA, 2022).

- **Educate student:** Explain what is not allowed and why (QAA, 2022; Manteufel *et al*, 2020) and foster a sense of pride in honest conduct, e.g. repeat the message and cultivate pride in the institution (Sambell *et al*, n. d.; QAA, 2022). Make sure that cheat has consequences (UNIwise, 2020). Ask students to sign an assignment checklist verifying that they have not resorted to academic dishonesty (Hendry, n. d.). Provide study support to develop student confidence (QAA, 2022).

Advice on student wellbeing and exam preparation

The included academic literature can be split into two themes: Student wellbeing and the evaluation of methods for exam preparation. Howcroft and Mercer (2022) picked up the wellbeing theme wholistically when they examined the Covid impact on students and pointed out that technology concerns may also extend to exams (e.g. internet unavailable during an exam). Alibak *et al* (2019) used a statistical approach to investigate online test anxiety and found that students overwhelmingly feel that working online during exams makes them feel uncomfortable and inefficient. Lessening this test anxiety may improve student performance (Prakasha *et al*, 2021). In addition to technical concerns, Prakasha *et al* (2021) highlighted students' apprehensions with respect to the exam format. For instance, the online format may not allow a student to go back, whereas paper based in-person exams allow this readily.

Regarding exam preparation, the work by Van Etten *et al* (1997) collected the set of beliefs students hold in this respect, which are mainly informed by personal experience, and divides them into motivation (especially good grades), strategies, emotions and the influence of external factors. Research by Kitsantas (2002) goes a step further and suggests that students who actively plan their revision in a strategic fashion (e.g. setting and achieving goals, asking for assistance or organizing/ transforming their notes) do better in exams. Drilling down even further, Jilakara and Waters (2020) examine seven study methods for preparing for physics exam and find that more active study methods, such as working through in-class problems, old exams or class presentations to be more helpful than just re-reading textbooks or quizzes.

The student guidance documents (Wood, 2020a; Wood, 2020b; Renfrew, 2020a; Renfrew, 2020b; Redrup, 2020) are more to the point and cover preparation and the actual exam taking. Their advice is summarized below:

- Exam preparation
    - **Know the exam arrangements** (including exam format).
    - **Organise your revision**: Make a revision timetable and get an overview of the subject (what are key concepts?)
    - **Practice active revision**: Make a mind-map, use past exam papers, index your material (bookmark useful content with post-it notes) and prepare a list of key information. Bear in mind that question will more focus on application then regurgitation.
    - Test your IT set up.
- Exam taking
    - **Create your own exam conditions**: Minimise distractions (e.g. turn off mobile phone, choose a quiet room), post an "exam in progress" sign on your door, make sure your desk is prepared and have a watch or clock to keep an eye on your time.
    - **Eat** before you begin.
    - **Exam analysis**: Get an overview of the exam and decide on the sequence. Before you answer a particular question analyse the question, this is not coursework so be succinct.
    - **Submit on time**: Allow time for scanning etc.

Case studies

Some of the case studies concentrated on evaluating ICBEs and UOBEs with respect to exam grades, e.g. Ural and Takaoğlu (2023) compared in-person and online physics multiple choice exams in terms of level (that is to say either belonging to the comprehension, application or analysis level) and grades. These researchers found that the two exams they compared used mainly application questions and the performance of the two cohorts (online: 167 students; in-person: 155) was not statistically different, although the online exam results were skewed towards the lower end of the grade spectrum. After a SWOT analysis Ashri and Sahoo (2021) looked at the performance of 212 business students who were give first a closed book exam paper and two days later the same exam questions in an open book format and found (unsurprisingly) a better performance under open book exam conditions. However, they admitted that not all other researchers found a grade improvement. The study by Chible (2021) showed that there was a relationship between attendance, continuous assessment and final multiple choice exam grades in a computer course, regardless of whether they were taken online or in person. Also in this study was the in-person exam more closely aligned to a normal distribution. Similarly, Harmon and Lambrinos (2008) developed a model to predict the student performance in an economics exam and found that, in an uninvigilated exam, this model did not perform nearly as well as under invigilated exam conditions leading them to the conclusion that cheating occurred when students were not supervised.

Other case studies, which are presented here in chronological order, not only describe the implementation of UOBEs, but also capture stake holder feedback. Kustijono and Budiningarti (2018) report on a pre-Covid study in which the authors try to establish the credibility of an online physics multiple choice question exam using evaluation sheets for the exam questions, the technical system and student feedback. This student evaluation suggested that this particular system was easy to operate, reduced cheating and created an exam atmosphere with relatively low levels of stress. Another pre-Covid study (Böhmer *et al*, 2018) started with identifying a suitable module and selected a low stake maths course preparing students for HE engineering studies which concluded with an uninvigilated 35 min multiple choice question exam. The authors reported that it took a relatively long time to prepare the exam questions (about 30 min per question) and that legal issues relating to privacy needed to be considered. Bhute *et al* (2020), on the other hand, reported on mock exams taken by 500 students to stress test the delivery of 40 different chemical engineering exams during the Covid-19 restrictions and included the results of their student survey. At the end of their UOBEs student were required to upload their scanned handwritten notes to their usual VLE. In addition to using handwriting as an anti-cheating measure, more conceptual problems were asked. This trial run allowed for the evaluation of instructions (e.g. print paper in case of intermittent internet connection), sufficiency of the allowed scan time (45 min) and online marking. Students commented that they wrote larger and clear so their exam paper would scan in legibly. The authors were concerned that only 60% of students had everything they needed for the exam, which may also relate to their exam environment. The benefits of UOBEs highlighted by the authors included fewer timetabling issues, reduced marking issues, improved turnaround time and savings due to less administration. A paper relating to dental students (Khalaf *et al*, 2020) is included here as it highlights possible pitfalls with invigilated online exams, such as background noise or technical issues. One interesting aspect relating to student satisfaction indicates that younger students and those with previous of online learning systems scored higher here and, generally, the staff was more satisfied than the students.

The final set of case studies described and reflected on the implementation of online exams. The pre-Covid paper (Mehrabian *et al*, 2008) relating to engineering and technology examinations mainly details concerns by this particular higher education provider which include exam integrity and the availability of invigilators to answer student queries. After that the authors present pass rate data dividing students into distance and on-campus learners, but it is not clear what the assessment method/conditions are, that is to say whether both the in-person and distance students sat the

same exam under the same conditions or not. Nonetheless this data shows a somewhat better performance by students who attended live classroom sessions. Before Smith (2021) details the development of an invigilated online exam environment he critically reflects on the prevalence of cheating and finds that, although some studies suggests that there is no real difference between on-campus and distance programmes, he cannot substantiate this from personal experience, thus emphasising the need for student supervision. The author also points out that following guidance on how to prepare an online quiz can be very time consuming with unsatisfactory results. In their reflection on the challenges of running online exams Chang *et al* (2021) elaborate on academic misconduct countermeasures, e.g. listing students suspected of cheating whose exam results are higher than their continuous assessment mark and inviting students for an oral exam to demonstrate their knowledge and understanding. El-Hashash (2022) describes the approach of two universities to biomedical online exams and includes their efforts to maintain academic integrity. These were, for instance, plagiarism detection software, a series of low-stage exams and educating both staff and students in academic misconduct policies. In his reflective note relating to calculus exams Jungic (2021) made a pertinent point on authentic assessment when he highlights that the scenario has to be carefully constructed so as not to distract from the actual exam task. Thereafter he explained how he used Covid infection rate data in his exam showing a good way of contextualising maths. After Jungic (2021) considered the main concerns with UOBE, protecting student wellbeing and protecting assessment integrity, he outlines how he split his exam into three individual sections for which each student had to upload their solution before the next one could be attempted. In his concluding discussion the author states that "this COVID-19-prompted teaching experiment turned out to be both a learning and liberating experience for me as an educator" (Jungic, 2021, p 619).

Discussion

Undoubtedly the effect of the Covid pandemic related restrictions on HE exams have set up a global experiment in education beyond compare. This review on advice and research in this area summarises some of the insight gained. These new perspectives cannot be ignored, but must be carefully evaluated to draw the right conclusions. One such conclusion could be that using UOBEs shifts the workload away from the administrative process of setting up and running ICBEs to examiners writing the exam papers and those charged with dealing with academic misconduct. The ramification of the advice on exam papers is that using in-class problems or questions for which the solution can be readily found must be avoided with the possible implication that an exam writer needs more time to set appropriate questions. Academic misconduct officers and related staff will need to be more proactive in detecting possible offenders through, e.g. detecting predicate and actual exam grade mismatch or online search for posted exam questions. As many of the submissions are handwritten normal detection software may be not very effective. Despite the fact that it is now illegal to run or promote commercial cheating sites in the UK, there is still more scope for accessing prohibited help during a UOBE than there is for an ICBE.

Exam preparation advice for students could take the form of an online live session, recorded sessions or written material and should strongly emphasize the need to prepare thoroughly for a UOBE as this type of exam will expect that material normally examined in an ICBE are readily available (e.g. memorized). One possible advice would be to organise or index material for easy search access. Advice for strategical planning of active revision should also be included as well as a briefing on academic misconduct policy and technology related advice, such as testing their IT infrastructure and writing more legibly for scanning.

Conclusions

The conclusions of the literature research can be summarized as follows:

- **UOBE exam questions**: Avoid recall questions and those questions for which an answer is easily found (e.g. online). Use questions for higher order thinking skills. Make sure all the necessary learning outcomes are covered. Consider individualising exam papers (e.g. through using different data sets) as this may aid detection. Include a watermark on all pages of exam papers. Only allow printing of exam paper (not copying of text).
- **Time limit etc**: Set appropriate limits that allow for scanning and some minor technical problems, but do not be too generous. Consider splitting one long exam into smaller sections/exams that need to be individually uploaded before access to the next part is granted.
- **Cheating will occur**: It is illegal to offer commercial cheating services in the UK. Invest in detection through, e. g. predicted grades (followed up by oral exams to verify grades of suspected cheater) or online exam question search.
- **Provide student advice for preparing and sitting exam a UOBE**: Include the format of the exam, how to strategically plan for active revision, how to organise their material and how to prepare their exam conditions (e.g. a notice on their door saying: "Exam in progress"). Encourage students to test their IT and write clearly to allow for loss of legibility because of scanning. Review academic misconduct policy and give reasons for students to follow it.

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Project outputs

- ESTEEM project report: A literature review on online maths heavy physics exams: How to write them and how to prepare students for them?
- Abstract submitted to the 4th Annual STEM Teaching Conference, 1st March 2023
- Abstract submitted to The 12th eSTEeM Annual Conference 2023, 19th-20th April 2023
- Accepted to present at Extended SHARE Scholarship special – up to two presentations and workshop, 2nd June 2023
- Disseminate to relevant staff tutor colleagues, relevant module chairs and director of studies

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