Outcomes from applying the inverted classroom to a first year structures module

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Abstract

The Institution of Structural Engineers has recently invested considerable effort to the thorny problem of how to improve understanding of structural behaviour amongst undergraduate students. This paper provides an account of action research in the application of inverted classroom principles to teaching first year undergraduate civil engineering students, which was undertaken as a response to disappointing academic performance of the 2012-13 cohort. The process was based around a virtual learning environment. The effect upon engagement was better than expected, and demonstrated that it is possible to engineer enhanced performance by increasing student interaction with a virtual learning environment in conjunction with a structured learning schedule.

Keywords Action research, on-line learning, virtual learning environment.

1.0 Introduction

The authors have previously reported a general improvement in performance of first year students studying structural engineering[1], over an eight year period. Academic performance, use of a virtual learning environment (VLE) and student satisfaction were shown to be linked for a cohort. This study followed eight cohorts through a module and attributed some of their improving performance to factors such as providing discipline specific worked examples, early adoption of a rich content VLE, and introduction of in-class testing which migrated to online testing.

Average academic performance for the 2012-13 cohort was, however, disappointing. This is shown in Figure 1. This performance was reflected across four of the six first year modules and resulted in almost a third of the cohort being required to resit one or more module assessments. As a consequence, there was a detrimental view of departmental progression when monitored by senior university administrators, who do not necessarily understand the need to maintain a minimum standard of performance (the public safety aspect of qualifying in civil engineering).

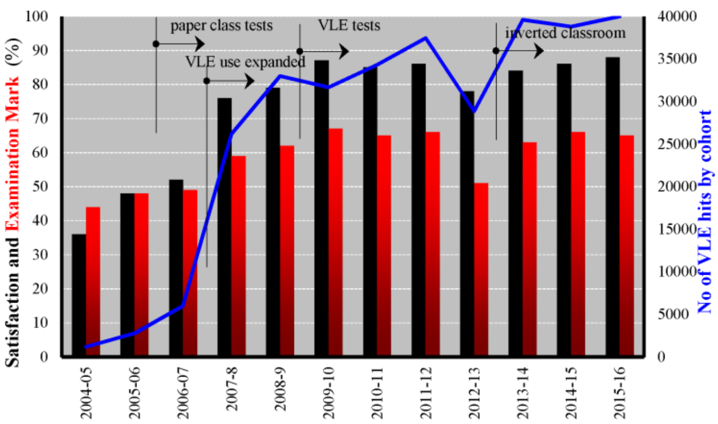

Fig. 1. Progression of first year cohort structures exam mark, satisfaction and VLE use with time.

A peer review was undertaken and some possible reasons identified for poor performance. These included a lack of commitment to learning (in good time) by some students; spasmodic attendance at lectures and tutorials by some students, as evidenced by attendance monitoring; and inadequate teaching methods or material. Since there had been no change in syllabus, teaching methods and material, assessments or staffing, it was concluded that this may be an aberration linked to the learning approach of a single cohort.

However, to mitigate the risk of future repetition, an action plan was devised which included the instigation of a departmental attendance monitoring system, to facilitate early identification of erratic turnout, as regular attendance is of most benefit to students at the extremes of academic performance[2]. Additionally, to define fine grained requirements for the weekly Design Exercise which knits five complete modules together and closely monitor quality and content which forms the final submission. Finally, to apply the inverted classroom principles to the first year structures module.

These three interventions were intended to foster engagement in learning by the students and allow the department to demonstrate student activity (or otherwise) to university administrators. In 2015 the university also instigated a new School based post, whose sole purpose was to assist struggling students to obtain the specific assistance they require to attain their best possible academic performance.

1.1 Research Methodology

Although this paper will concentrate on post-inverted classroom outcomes, the module has been subject to development since 2005. Initially the intended learning gain was focused upon knowledge and understanding of the topic, which was to be quantitatively measured by improved student progression. However, it became evident that students wanted a more holistic understanding of civil engineering design which led to the introduction of a separately assessed Design Exercise. The learning gains associated with this are work readiness and interview performance but were perceived as much more difficult to quantify.

In 2013 there was no intention to undertake research into the effects of adopting the inverted classroom, so conclusions reported here are merely derived from data which the module leader obtained and analysed annually for the purpose of module review. The majority of data was obtained from the Blackboard VLE system by setting levels of data tracking. Assessment data was recorded in standard university systems.

Student identification numbers were used to match data entries and ensure anonymity.

This is a cross-sectional study which follows different cohorts of students at the same point in their degree. Comparisons are presented between data before and after the introduction of the inverted classroom. The 2011-12 cohort was selected as representative of pre-introduction data. Data for the initial post-introduction cohort in 2013-14 is generally used for comparison but in some figures all available data for subsequent cohorts is also presented.

The only changes made to the module before the start of the 2013-14 academic year were:

- An update to the module handbook which explained the actions students were expected to undertake on a weekly basis, encapsulated in a one page weekly timetable.
- The instigation of a weekly email reminding students what learning activities they were expected to engage in during the week.
- The introduction of weekly formative tests, located on the VLE.
- The requirement for students to engage in pre-learning which constituted reading part of the printed handbook and watching a VLE based video (the handbook and videos already existed on the VLE).

In addition to the structured approach outlined above, it is important to appreciate the constraints and challenges that the students on the programme face and this will be outlined in the following sections.

1.2 Socio-economic Factors

If it is accepted that every student who has met the programme entry requirements has the potential to succeed in civil engineering, then the function of a lecturer is to facilitate acquisition of knowledge and understanding by the student. Unfortunately, all students are not labouring under the same conditions. Financial constraints may be a significant factor in student behaviour – a large proportion of Salford's civil engineering students must now support themselves and/or dependants during their education by working part-time. A straw poll in 2015 revealed this to be almost a fifth of the first year cohort. Bather[3] reports on social demands pertinent to civil engineering students and how these can affect student engagement. One of his key findings is that many students have difficulty finding the recommended study time. *A time flexible learning system is therefore advantageous as many students must now fit study around other commitments*.

As reported in the education press[4], there is a financial disincentive for universities to admit students from lower socio-economic groups, as they are more likely to drop out of university, this has a detrimental affect upon widening participation. The correlation of entrants from the lowest socio-economic groups and first year drop-out in UK universities[5] shows an inverted logarithmic trend, where Salford has a first year drop-out rate approaching 11% and approximately 40% of students coming from the lowest socio-economic groups. It is not surprising that many students who are amongst the first in their family to attend university, also fall into the group of students who would be categorised in the lower socio-economic groups and the group who must work to support their studies. Therefore, *a learning system which promotes the possibility of student engagement will assist in reducing the constraints upon students who might otherwise fail to complete their degree.*

1.3 Learning Styles

Research[6] provides a useful insight into learning styles which are relevant to engineers using a VLE as part of a blended learning approach. They suggest that engineering students naturally adopt an inductive learning style (general rules are formed from particular observations); however, the natural teaching style is the opposite of this (general rules are delivered first). Furthermore, they found that most engineering students identify themselves as active experimenters rather than reflective observers. So, the traditional didactic lecture, where students are passive, is of little use as both active experimenter and reflective observer cannot learn effectively.

This rather simplistic view of engineering students' learning styles can be updated in view of more recent research[7]. A far more complex interaction of variables are now considered to form an individual's range of cognitive styles, and that a learner will further develop use of a cognitive style if it is successful. It is known that successful learners develop cognitive style flexibility and that a learner may operate several cognitive styles at different levels. It is therefore better that teaching approaches are tailored to the specific task, rather than the style of a learner or cohort.

The use of *a VLE therefore offers engineering students a tool to aid exploration at their own pace*[8]. Furthermore, most engineering students are sequential learners (linear textbooks suit their learning style) so VLE content must be arranged with some care. Some students are global learners and need to see the bigger picture before grasping what may seem to be simple concepts (students who have light bulb moments) so it is important that students experience the practical use of the content they are learning (e.g. through a Design Exercise).

2.0 The Inverted Classroom

There are published accounts of successful application of the inverted classroom in chemical engineering, chemistry and physics[9 &10], such that the Higher Education Academy STEM discipline has subsequently published a case study[11] demonstrating positive learning outcomes are possible.

The inverted classroom is a system where students acquire module content via structured self study in advance of lectures. This may be based around a VLE and offers the chance to move away from a didactic lecture style to a student centred problem solving system. Understanding is regularly tested using online systems. The principal differences between this and traditional didactic approaches are shown in Figure 2.

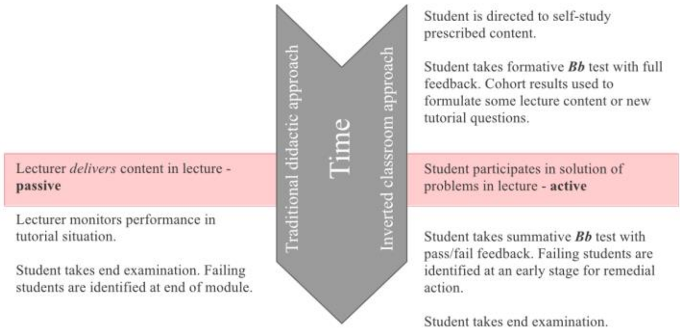

Fig. 2. Traditional and inverted classroom process.

An excellent historical review of developments in the inverted classroom as applied to engineering programmes in the USA is available[8]. The review covers a six year period and includes 17 papers which study modules that are significantly less mathematical than the topic of this paper. Nevertheless, the authors make the important observation that the rise of inverted classroom techniques have happened in conjunction with the proliferation of cheap, accessible ubiquitous computing and its association with the lifestyle of young people. They also recommend that instructional videos should be limited to 10 minutes duration; that there are weekly online assessments and classroom quizzes; and students should spend some of the weekly lecture time working on solving coursework problems. Most studies reported show a small or insignificant statistical performance improvement in adopting the inverted classroom but it is growing in popularity with both lecturers and students. Students are reported to believe that inverted classroom, or something like it, is the future of higher education as it provides organised and flexible learning and opportunities for meaningful classroom interaction.

The inverted classroom should therefore establish relevance of the learning material; direct students to introductory learning material on a predetermined timetable; identify sources of further learning, possibly using other modes of learning; provide problems to solve which are graded to improve understanding; assess performance and provide feedback which allows students to gauge their progress; provide more *lecture time which can be devoted to application of, rather than acquisition of, theory*[12]*; be time flexible, so students can structure their learning around other commitments; and be location flexible, so that students can learn where it best suits them.*

2.1 Application of Inverted Classroom Approach to the Module

The specific application at Salford used the existing module handbook, which is issued to all students in hardcopy but other researchers have based their self study on a generally available text book. The syllabus, schedule of testing and time commitment expectation have not changed since the inception of the module.

Two types of testing were used during the module:

1. Formative tests (not credit bearing) were run at the end of most weeks, the test could be completed at any time between noon on Friday and 8:00pm on Sunday. This left a day for the module leader to assimilate common misunderstandings or areas of difficulty from the student's answers, which were then used to inform changes to the lecture content.

2. Summative testing (credit bearing) was used at four points during the year. These tests relate to core capabilities expected from first year students, and were directly linked to examination content. They were timed to allow students who had underperformed in the formative tests, to obtain and act upon feedback before attempting summative testing.

The purpose of formative testing is to facilitate engagement by the student, whereas the purpose of summative testing is to quantify knowledge and understanding. All testing was undertaken on the Blackboard 9 VLE system, where pools of questions were created by the lecturer, such that students are presented with a timed, potentially unique, test of randomly arranged questions.

Weekly self-study was an open ended activity. Students were expected to read the module handbook section relating to the next week's topic and watch the topic lecture mounted on Blackboard as a video. The handbook then offered a range of further sources of learning material, many of which are held on the module VLE site, these include structured tutorial questions and solutions; extracts from journal papers and books; links to online texts and worked examples; and links to rich online content such as short video lectures, games and puzzles. The diversity of learning sources, all integrated into a familiar environment encouraged the students to explore the topic using their own initiative and fosters a disruptive learning ideology.

The student must then take a short VLE based test, typically five questions. A *word cloud* was then created to represent the problems encountered each week by students in the self-study period. These are reported in the last question of each formative VLE test and form a good visual opener to each lecture. Generally, the majority of a cohort would identify a similar problem, which could be clarified at the start of the lecture period and resolved by working through a practical example. The cycle is depicted in Figure 3.

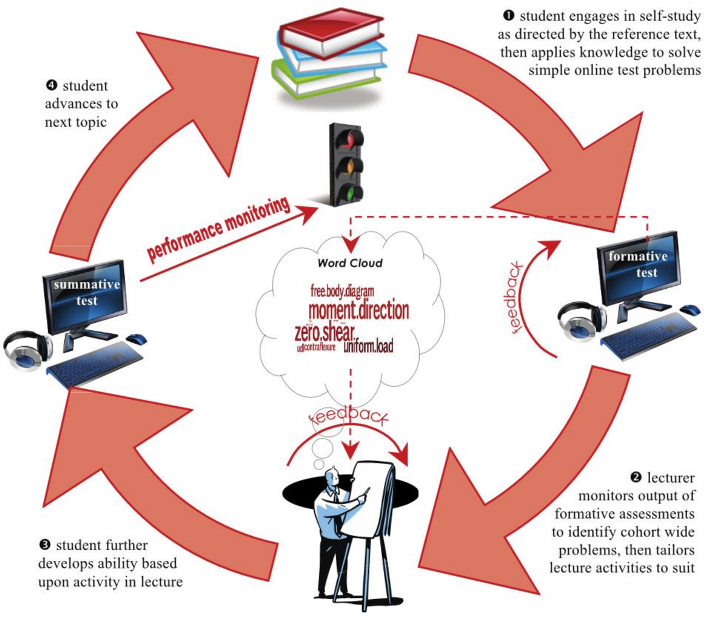

Fig. 3. The weekly cycle of self-study and testing.

For a cohort of students, the spread of VLE usage across a typical in-semester week suggests there is no preferable time to study since use was evenly spread across every day except Saturday. Almost 50% of students complete the formative tests at the deadline, on Sunday evening.

2.2 Challenges

The initial time demand upon a lecturer to establish a viable learning schedule, rich content VLE and online testing is high, furthermore the content requires periodic review and manicuring.

Many inverted classroom practitioners have the assistance of their PhD students to analyse formative test feedback and amend the weekly lecture content but the authors found it consumed little more than an hour per week, which reduces with repetition of the module, as there are a limited number of unexpected problems to be encountered, allowing gaps to be plugged for the next year in advance.

Since lecture periods may be devoted to tutorial activities, it is important that students spend this time actively engaged in learning. Lecturers who favour the use of Powerpoint often face the challenge of engaging students who know an electronic copy of the lecture will be available later. The answer may be to incorporate student response systems, as there is a fashion for the use of *clickers* in lectures to enhance interactivity[13], which is particularly appropriate when gathering improvement data. A voting analysis tool has been developed[14] which allow students to compete over a complete module for a prize awarded to the student who gave the most correct answers to clicker questions. There have been positive reports[15] on the use of web based clickers but on-line response systems are now easy to adopt as internet mobile devices are endemic amongst students. However, the object is merely to engage the students in active learning, so presenting a short problem and offering two possible but numerically similar answers has been found to be sufficient to stir up discussion and competition. The authors have found it expedient to use Kahoot! to motivate students to complete in-class exercises by declaring the answers will be revealed in a quiz. Kahoot! (free at www.create.kahoot.it) offers an additional time related element of competition to rank those who obtain the correct answer. This system also has the advantages of only requiring internet access, and creates an attendance list as a by-product.

Once students have arrived at an incorrect answer, they were encouraged to consult a student who arrived at a correct answer. The lecturer need therefore only deal with students who have either established a fundamental misunderstanding of the theory or are incapable of operating their pocket calculator. This promotes focussed in-class discussion and peer-to-peer learning.

These principles are further reinforced through the application of the newly acquired skills and knowledge to a practical scenario during the *Design Exercise* progress meetings each Friday morning. These sessions last typically three hours, with the output from the design groups being evaluated by Chartered Engineers, and formative feedback given. This is in addition to the peer-to-peer learning that has happened during the week as the group progresses towards that week's milestone. At the end of each semester a formal submission of the work is made to enable summative feedback to be applied to the portfolio. Figure 4 depicts the progression of learning activity into the cross-module *Design Exercise*.

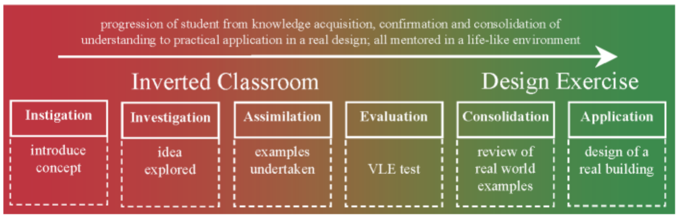

Fig. 4. Progression of learning activity into the cross-module Design Exercise.

3.0 Results

Summative VLE testing has been part of the first year structures module for many years. There were four VLE based summative tests during the year, which could only be taken at prescribed points in time but could be taken anywhere, subject to an internet connection. Participation rates were 96% or better. Students who failed were encouraged to retake the test, and results were capped at the pass mark of 40%.

3.1 Module Grades

The examination mark was calculated as a composite which awarded 5% for each VLE summative test and 80% for the end examination. This was intended to provide an incentive for participation. However, where there was advantage for the student, the VLE test marks were ignored. Approximately three quarters of students performed significantly better in the end examination than the summative tests, and so the summative VLE tests had no effect upon their final mark. However, a large proportion of students who obtained a marginal module pass, were students who benefited from a composite examination mark.

Student performance in summative tests and end examination are depicted in Figure 5. Although not a strong correlation (coefficient of determination, R^2=0.52), there is a direct relationship between performance in summative tests and end examination.

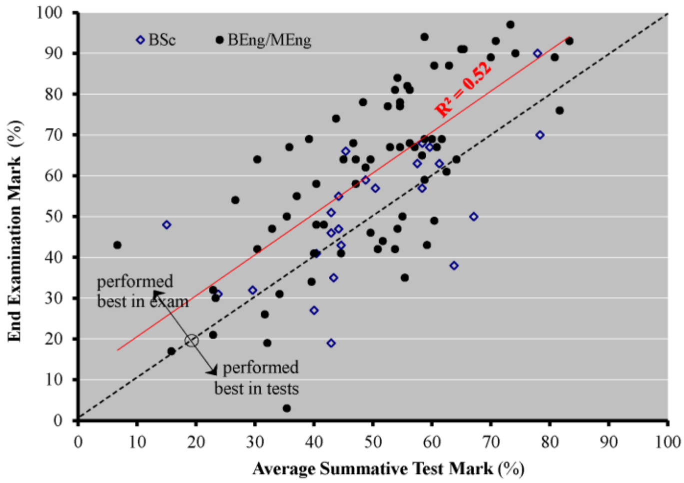

Fig. 5. Correlation of summative VLE test and examination marks, 2013-14 cohort.

Formative VLE testing was introduced to the module specifically as part of the inverted classroom experiment. There were fifteen VLE based formative tests during the year, which were spread over both semesters and each could be taken at any point over a two day period, subject to an internet connection. Participation rates ranged from 67% to 90%. These tests were more concerned with principles than computation, and included comprehensive feedback. Formative feedback was sufficiently detailed to allow students to self-correct, leading to self-evaluation and promoting deeper learning[16].

The distribution of examination marks had traditionally followed a slightly skewed normal distribution, as shown on Figure 6 for the 2011-13 cohorts. There were no students scoring in the 91%+ band and a disappointing number of students who scored less than 30%. It was this type of observation which had prompted changes to assessment for this module from 2006.

Results for 2013-14 are significantly different. The proportion of students failing the end examination dropped by 10%, the proportion of students achieving a first class mark increased by 10%, and the proportion of students achieving a mark over

80% almost tripled. The overall module pass rate remained virtually unchanged because there were significantly fewer students scoring in the 51-60% band. In the following two years similar changes were observed, suggesting that the improvements are related to elements of the inverted classroom.

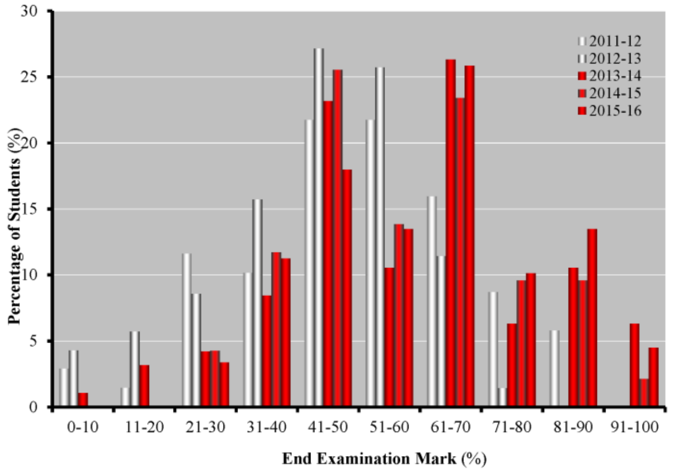

Fig. 6. Histogram of student examination performance.

3.2 Participation Trends

Further analysis of the VLE use data presents significant differences in student performance before and after the introduction of inverted classroom principles.

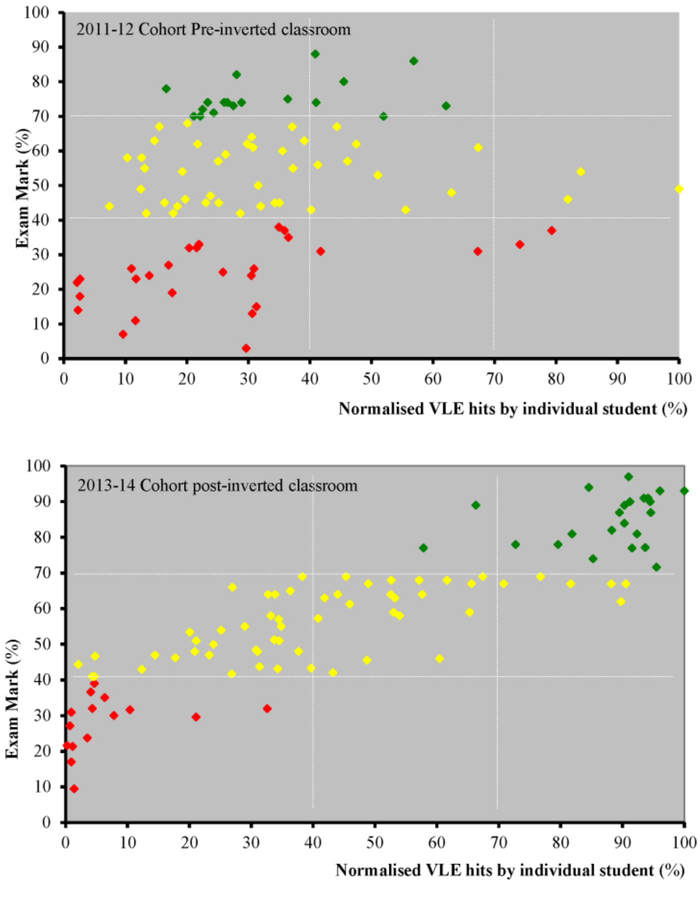

Fig. 7. Correlation of student examination performance with normalised VLE use.

Figure 7 shows the relationship between VLE hits made by each student, and their end examination mark. This figure presents VLE hits normalised as a percentage of the maxima. For the 2011-12 cohort there is no useful correlation (R^2=0.09) but for the 2013-14 cohort the linear correlation is significantly stronger (R^2=0.79). Each data point represents a student, and each is coloured relating to a mark band (red < 40%, yellow 41-69%, green > 70%).

It should be noted that all the students who achieved less than 40% in the end examination made less than 40% of the normalised VLE maxima hits. Conversely, virtually all the students who achieved more than 70% in the end examination made more than 70% of the normalised VLE maxima hits.

It was believed that use of a VLE may be of greater benefit to particular groups of students. To investigate this, the students were grouped by origin into Overseas, European Union or United Kingdom. This may crudely separate native English speakers, and offer some insight into whether language is a significant barrier to learning structural engineering.

Figure 8 shows the relationship between VLE hits made by each student, and their end examination mark. For the 2011-12 cohort there are very weak correlations for all origins. For the 2013-14 cohort the linear correlation is significantly stronger, and furthermore there is little to separate the correlations for each student origin group.

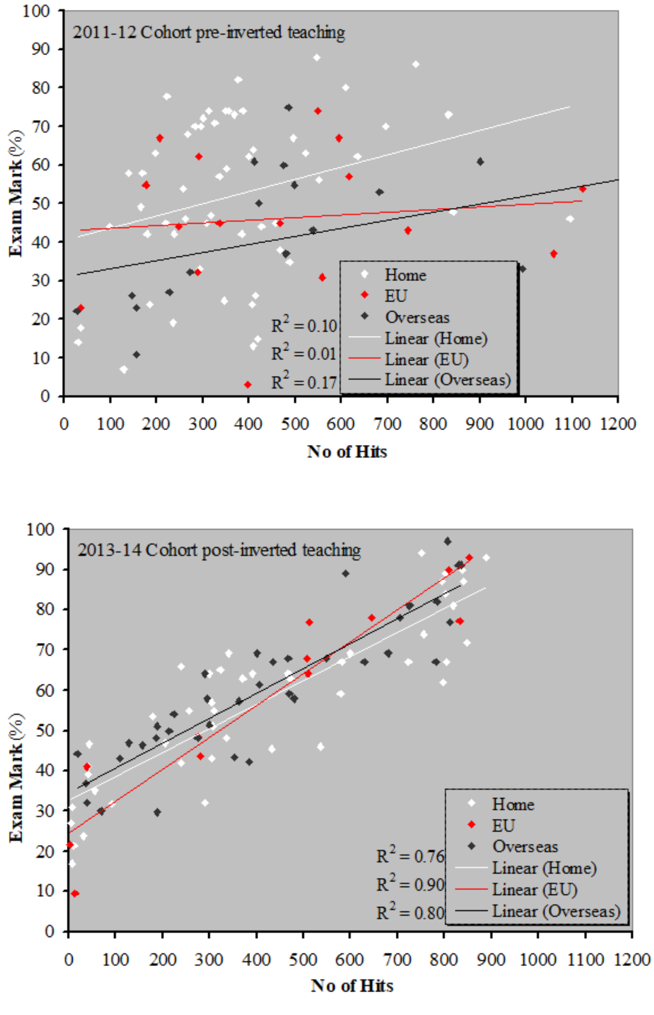

Fig. 8. Correlation of student examination performance with VLE use.

This suggests that the academic performance of structural engineering students may well be more predictable when they are exposed to a highly structured learning system but there should be no advantage for native English speakers.

4.0 Discussion

4.1 Applying the Inverted Classroom

Mirroring traditional didactic learning approaches in a VLE as a key failure identified in some online education systems[17]. Thus, the improved student satisfaction reported here may be linked to diversification of VLE content (away from lecture material) to other rich content such as online videos, real-time games and puzzles.

Although use of online lecture content is generally accepted as a positive move, some students[18] dislike this impersonal delivery mode, similar opinions are expressed[19] regarding online testing, until students are familiar with the relevant computer system. This is not an opinion expressed by the student population studied for this paper although there have been several cases of students initially failing to complete a test due to network problems, and being discouraged from engaging thereafter. It should be noted that the online content delivery used in this intervention is not the sole delivery method.

Much research on the use of a VLE[20] demonstrate little or no correlation between use of a VLE and *individual* academic performance. An investigation of blended learning which included use of a VLE[21] concluded that the overall time spent on using module resources correlates more highly with mean examination score than either lecture attendance or time spent reading journal papers. So there does not appear to be agreement on the merits of incorporating VLE tools into teaching. However, there is little doubt that virtual learning environments provide a means of enhancing engagement amongst cohorts of students which exhibit ever increasing diversification[22] but converging IT skills.

The inverted teaching style therefore, will only suit those lecturers who are willing to trust their students to take control of their own learning and adopt a facilitator role in the lecture theatre. This is described[23] as relinquishing authoritarian control and allowing the intrusion of apparent chaos. This may appear to be imprudent but gains a weekly assessment of performance with which to monitor student progress. It should be acknowledged that this intervention embodied a transfer of responsibility for weekly learning to students but did this within a rigid timetable which was declared to students at the beginning of the module. They were also aware that engagement was being monitored.

First year structures teaching at Salford has for many years involved a tutorial safety net called *Structurescope* (the university offers *Mathscope* and *Wordscope* centrally), which was in little demand after the inverted classroom was instigated, and therefore effectively reduced workload for staff during semester. However, in the two weeks before the end examination there was a resurgence in demand. Students who attended these sessions were noticeably better prepared to elicit answers to their questions, than students in previous years. For example, a typical student arriving at Structurescope with a partly answered question will also be accessing the VLE via a laptop, with a video and an electronic worked example opened at appropriate points.

Fig. 5 shows there is a useful correlation between summative assessment and end examination performance, suggesting early assessment preparation is a useful part of the revision process. From the perspective of a student, learning is a means of passing assessments and may lead to adoption of shallow learning. The principles of constructive alignment[24] in teaching and assessment methods were applied to encourage deep learning. Students were expressly informed that there was a progression from weekly learning to formative and summative assessment, to end examination, and finally to design exercise. This has engendered a desire to understand and apply principles, since the final assessments require students to solve problems not regurgitate facts.

Several researchers have established no link between VLE use and assessment performance but one study[25] of electrical and mechanical engineers did suggest that performance had been marginally improved when VLE content was richer than a mere repository for notes, and supports the outcome seen in this intervention.

The *Design Exercise* is a cross module complementary group activity which further increases student interaction and fosters a collegial atmosphere. This weekly activity also reflects the principles of the inverted classroom because the students receive *feed-back* on the previous week’s work and *feed-forward* on where to direct the next week’s activity. It is the perfect opportunity to apply the *show, don’t tell* principle. Feedback on performance[26] is an important element of student motivation, and the type of assessment deployed will affect the approach to learning adopted by the student. Additionally, *feed-forward* is identified as a means of fostering continual engagement. Since the *Design Exercise* is a practical application of what students have learned in all six first year modules, it enhances engagement amongst groups of students by providing an outlet for innovation and introduces an element of peer pressure to contribute and reach a quality threshold.

4.2 Making the Best Use of a VLE

The authors have previously shown that student use of a VLE through an academic year is closely related to assessment activities such as laboratory sessions and examinations, supporting the maxim *students learn what is assessed not what is taught*. VLE usage statistics also suggest that use across the days of a week was remarkably even, and use across a day was predominantly between 9:00am and 5:00pm (about 50%) but 10% of use was between midnight and 9:00am, the remainder being late evening use.

From the beginning of the 2015/16 academic year Blackboard 9 has been available to students in the form of a mobile phone application, which presents the real possibility of learning happening anywhere that a mobile phone signal exists. However, there is no evidence that this development has significantly changed the behaviour of students in relation to time of study.

4.3 The Applicability of Results

From the 2008-09 cohort, the number of first year civil engineering students has remained stable at approximately 90. The cohorts in consecutive years have differed in size by less than 5%. The programme entry standard has remained unchanged in terms of subjects and minimum attainment, although variation in entry point score has varied by more than 10% since 2008.

In 2013-14 the proportion of international students was 16% and this has grown to 28% in 2016-17. This has brought challenges in respect of the standard of written English and comprehension but appears to have had no effect upon the overall performance of a cohort in a largely mathematical subject. Over the same period the number of female students has also increased to its current level of 26%.

In an editorial about the inverted classroom in STEM subjects[27] the point is made that there are normally statistical problems associated with numerical evidence presented for and against academic improvements attributed to inverted classroom studies. However, there is now an unassailable body of evidence that active learning styles produce superior results to traditional lecturing styles, and so it no longer makes sense to use traditional lecturing as the statistical control. Previous studies have solely addressed numerical evidence in terms of module assessment marks, so it is perhaps unsurprising that improvements are very modest since the intended outcome is increased engagement rather than academic performance.

This study, like many before it, does not show any improvement in average cohort performance. It does however identify some useful changes in student behaviour which have continued over subsequent years. Fig. 7 shows that when students are subjected to a highly structured application of the inverted classroom, there is a strong relationship between their final examination mark and the amount of use they make of the VLE.

In this study, comparison is made of the performance of entire cohorts taking the same module in different years. It must therefore be acknowledged that any perceived improvement in academic performance, satisfaction or knowledge and understanding is a result of studying general trends over a period of several years. No claims can be made that adopting the inverted classroom can improve the performance of an individual student. Additionally, since the learning system is a blend of inverted techniques, improved VLE content and closer monitoring of progress, it is possible that students are simply better prepared to take advantage of the improved learning environment and are making a time commitment because they are aware of being monitored.

5.0 Conclusion

The inverted classroom can be configured in many ways to suit the particular needs of a cohort of students. It can offer great time flexibility for learning and assessment, can incorporate technology to improve engagement and address active learning styles in the lecture theatre.

The inverted classroom will suit students who arrive at university accustomed to a highly didactic and finely structured system of secondary education because it offers a smoother transition to becoming an independent higher education learner.

Clearly, several new interventions were introduced for the 2013-14 cohort which were designed to improve student engagement, so inverted teaching may not be the only explanation for improvement. The outcome of examination performance has exceeded expectations, although this has resulted in a pronounced change in examination mark distribution to a *double-peak* distribution of acceptable and excellent results.

The addition of electronic learning activities centred around the VLE including a weekly email reminder, weekly formative tests and focussed pre-learning, were the only changes made within this module. The authors had initially believed that a direct improvement in individual student summative performance would result in these changes, which is not the case. This suggests that close educational instruction remains a key feature of success in understanding structural behaviour.

At the extremes of academic performance, there is a direct correlation between examination performance and VLE use when a structured schedule of work is adopted by learners. This is believed to be because learning activity is now focussed around the VLE against a structured schedule of topics, with feedback on performance.

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