A ***FLIPPED CLASSROOM*** IN ENGINEERING EDUCATION – STUDENT PERCEPTION AND EFFECT ON LEARNING

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Abstract

This study examines a module taught on an engineering programme using a *flipped* approach, to students who otherwise were taught using a traditional lecture-seminar model. Students' perceptions of the module and their own evaluation of their use of learning materials were examined, using questionnaires and interviews. Results indicated a high level of engagement, but lower usage of the theory based learning materials, with preference for practical materials. A slight increase in GPA for the flipped classroom cohort was not statistically significant, and the proportion of high achieving students did not change. However, the module reduced the failure rate to zero, indicating that this approach particularly benefits weaker students, while not reducing the performance of abler students.

Keywords: Flipped Classroom, Engineering, Digital Native, Net Generation.

Introduction

In many engineering subjects the delivery patterns of degree courses have remained fundamentally the same over the past two or three decades, based on a lecture-seminar pattern, in which core information is 'delivered' by a lecturer, and which uses predominantly written supporting materials in order to scaffold understanding of this material.

In the same period, the nature of engineering education has changed. From being largely calculation based, in which the core skillset was the ability to undertake mathematical calculations, a significant proportion of engineering education now focuses on practical application of knowledge, using software packages for calculation, simulation and modelling in areas from acoustical engineering and architecture, to computer games programming (Barlow & Lancastle, 2009).

This requires courses to allocate a significant amount of time to the teaching of the software packages themselves, reducing time spent in actually applying the software to solving problems. This is exacerbated by a traditional lecture-seminar delivery pattern, where there is relatively little time spent on the practical aspects of a course, which tend to be allocated to private study. With lecture led delivery, some students will struggle to maintain the presentation's pace, while others find it too slow, resulting in frustration for both groups, and potentially reducing engagement and progress (Taber, 2000).

The flipped classroom model makes use of independent learning time for students to learn *knowledge based* materials, enabling classroom time to be devoted to more detailed examination of the topic – through seminars, practical tasks and experiential learning. There are several studies that report positively on its implementation in terms of student engagement.

However, over this time, the technology supporting flipped classroom has changed, and there is also a considerable amount of literature that examines the changing study patterns of students in the *net generation* (Tapscott, 1998). There are therefore questions regarding how current students perceive and respond to a flipped classroom. In particular, do students actually utilise the flipped classroom resources in the manner in which the lecturer anticipates? This paper examines the implementation of a flipped classroom approach on a module delivered to two engineering courses that otherwise had a 'traditional' delivery pattern and compares academic results to the previous cohort of the same module, which was delivered in a traditional manner.

Background

The flipped classroom is a pedagogical model in which the lecture and coursework materials are reversed (Mazur, 2009). With the availability of internet delivery platforms including Virtual Learning Environments (VLEs) and Social Media video sites such as YouTube and Vimeo, contemporary flipped classroom approaches tend to focus on the use of video to provide lecture materials, with classroom time being used for quizzes, discussions or practical work. This allows students to cover theoretical material and practical tutorials at their own pace, to catch up easily on missed work, and to review materials. It further allows the maximising of access to specialist facilities.

Although there is a growing body of practice of lecturers and institutions using the approach, there is still a limited amount of research examining how well flipped classrooms actually work and in what way students engage with the materials that form the basis of the flipped classroom (Goodwin & Miller, 2013), and there is limited academic literature on quantitative analysis of the effectiveness of the flipped classroom. Much existing research has focused on student enjoyment/engagement with materials (e.g., Bergman & Sams, 2012) and increased student-teaching interaction (Greenberg, Medlock, & Stephens, 2011).

One of the key concepts of the flipped classroom is that of connecting with students who are from the *net generation* (Tapscott, 1998), also referred to as *digital natives* (Prensky, 2001a). These students were born between the late 1970s and the year 2000, and have had the majority of their education since the advent of the Internet. Digital natives are considered to be digitally literate, able to use devices and find information on the Internet with ease (Oblinger & Oblinger, 2005), with a high ability to read visual images, and to be able to shift attention rapidly from one task to another. They thrive on use of graphics rather than text, need immediate gratification for information requirements and like to parallel process and multitask (Prensky, 2001b).

Exponents of the concept of the net generation have also identified that this group are *experiential learners*, who learn by doing, rather than being told what to do (Tapscott, 1998). Several authors claim that this group expect technology to be integral into their educational experience (e.g., Oblinger & Oblinger, 2005; Prensky, 2001a; Tapscott, 1998). Prensky goes so far as to say that the brains of digital natives are different to those of previous generations, primarily driven by changes in technology (Jones & Shao, 2011).

The flipped classroom is seen by many as an approach that "speaks the language of today's students" (Bergmann & Sams 2012, p. 20), addressing the needs of the digital native. However, some researchers have cast doubt on this concept. A large scale

literature review by the UK Higher Education Academy found, "There is no obvious or consistent demand from students for changes to pedagogy at university," (Jones & Shao, 2011, p. 2), while Kennedy, Judd, Dalgarno, and Waycott (2010) found that a lot of understanding of the net generation is based on anecdotal evidence or untested assumptions, and this generation has "instead shown to possess a diverse range of technology skills and preferences" (p. 332). Calderwood, Ackerman, and Conklin (2014) also found that task switching was linked to a negative effect on performance in homework.

Method

The module used teaches the design and integration of sound for video games to final-year undergraduate students and is taught to multiple groups from different subject specialisms. The module has core elements of fundamental theory, as well as a significant element of learning how to apply these to the development of computer games using specific software packages. The mixed cohort of the group meant that students had different levels of prior experience, with some highly experienced in audio, but not software development, and others with experience in software development but with little audio knowledge.

The course delivery model had previously been based on a two-hour per week seminar, in which the first hour was lecture-based, predominantly focusing on theory, while the second hour was tutorial, with practical demonstrations by the lecturer and teaching assistant as well as some student time to work on practical exercises.

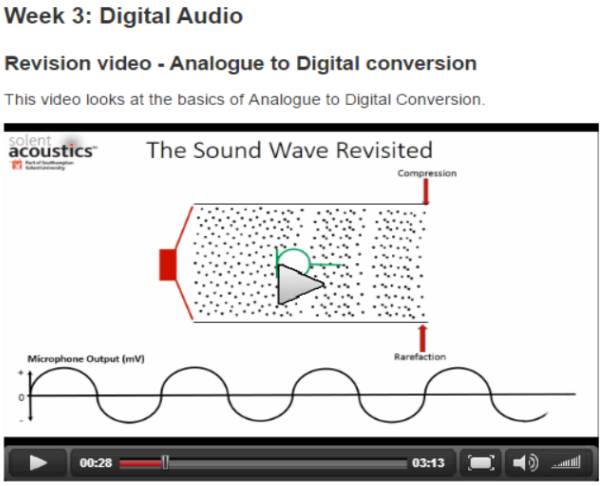

Figure 1. A video lecture on the virtual learning environment.

The delivery pattern was redeveloped to remove the lecture element and to deliver all lecture material through video via the university's Moodle-based VLE. Each week throughout the course, a number of learning materials were provided in advance of the class, including two to three original videos of around 7-10 minutes each (recorded by the lecturer), covering theoretical and software based (practical) learning material (Figure 1) as well as assets that they would need to use to complete the tasks in the classroom sessions. Both written and video tutorials were provided for each subject covered, allowing students the choice of which material they preferred to use.

The two-hour weekly seminar was retained, but class time was used for independent learning, with students able to apply the material covered to practical learning tasks. This was supported by a lecturer and a teaching assistant, who were able to provide student support in the classroom on a 1:1 basis.

Assessment of the module was based on two practical assignments, in which students were required to plan and undertake the audio implementation for a level of a video game developed specifically for the assessment. Students were required to provide full documentation and a technical report that explained the underpinning theory behind their approach to the development. The same assessment brief (though with some minor variations in the game developed for the assessment) was used for both the previous cohort and the *flipped classroom* cohort.

Theoretical Framework

The justification for the flipped classroom approach was focused not on reducing costly classroom time delivering material best placed in lectures, but on applying a more student-centred approach to learning. Whilst there were elements of underpinning theory, the module had a number of quite practical learning outcomes, and the students were expected to develop a set of practical skills. Many of the students started the module with poor independent learning habits, a highly strategic approach to study and assessment, and limited intrinsic motivation, while the different specialisms within the cohort meant that different paces of learning were inevitable on any topic.

Like many students, the group had responded well in the past to problem-based and experiential learning activities. Problem-based learning centres around the development of skills, upon which it has been shown to have a positive effect (Dochy, Segers, Van den Bossche, & Gijbels, 2003). It can be described as having goals that include developing effective problem-solving skills, self-directed learning skills and intrinsic motivation (Hmelo-Silver, 2004).

However, it has been shown that effective problem-based learning is often collaborative or cooperative (Prince, 2004) and less appropriate for the solo-learner. Also, the effect of problem-based learning on knowledge is less clear, and has even been shown to be negative in some cases (Gijbels, Dochy, Van den Bossche, &Segers, 2005), which could be a significant issue for students with weak theoretical foundations.

It has been shown that curiosity is stimulated when students are aware of manageable gaps in their knowledge, and that curiosity has a direct impact upon intrinsic motivation (Loewenstein, 1994). An earlier study on similar students showed that knowledge gaps that are too great may demotivate students, as they will be deterred from attempting to gain a new learning level if they perceive that new level to be unattainable. Conversely, if the gap is too small, students exhibit little enthusiasm for the task as their curiosity isn't sufficiently stimulated (Lancastle, 2012).

Data Collection

This study used a mixed methodology in order to assess both quantitative and qualitative data regarding student perceptions and use of learning materials. Students were asked to complete an anonymised 7-point online questionnaire mid-way through the unit, which addressed some basic points of usage and student perceptions of their

own learning using Likert scales. From a cohort of 42 students, 19 completed this questionnaire.

At the end of the unit, students were then asked to complete a 31-point online questionnaire, which was embedded into the module's VLE page. This considered their subjective response to the learning materials, their preference for video- or text-based learning materials, their use of learning materials, including number of times accessed, pattern and reasons for use, and their use of video feedback. Some open text questions were also included to allow students to express more detailed feedback regarding the unit materials and approach. Ten students of a cohort of 42 completed this questionnaire. Students who responded to the final questionnaire were then followed up with a short semi-structured interview in order to allow them to further discuss their perceptions of the unit and the use of material and to express this in their own words.

Quantitative data on grade performance was also collected from both the previous cohort, which had followed the traditional course delivery pattern, and the current cohort who had used the flipped classroom approach, for comparison on the effect of performance on grades.

Results

Both the mid-unit questionnaire results (Figure 2) and the end of unit questionnaire results (Figure 3) in this study reported increased satisfaction, with the majority of students expressing preference for the video based learning materials and high levels of engagement compared to traditional models of delivery.

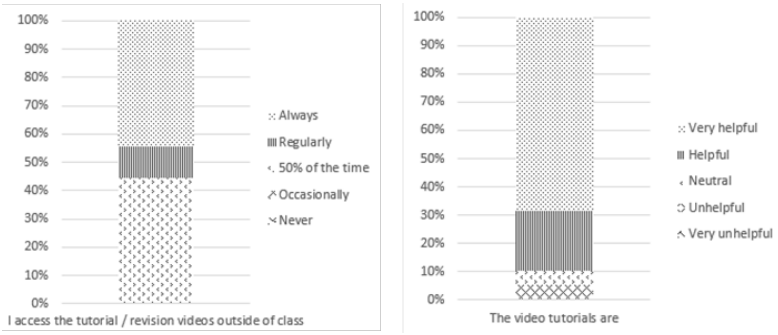

Figure 2. Mid-unit perspectives of learning materials.

Ninety percent of respondents of the mid-unit questionnaire judged the videos 'helpful' or 'very helpful' in their learning (Figure 2); 68% reported preference for learning independently using guidance material; and 45% prefer asking questions and getting one-on-one support. By contrast, only 32% reported a preference for learning by lecturer demonstration.

The end of unit questionnaire had a similar response, with 70% of respondents accessing the learning materials at least 3-4 times per week, and 50% viewing video materials before the session "most weeks." One hundred percent of respondents rated the video tutorials as 'helpful' or 'very helpful.' Seventy percent of the respondents rated the unit structure as making their learning easier, with the remainder neutral (Figure 4).

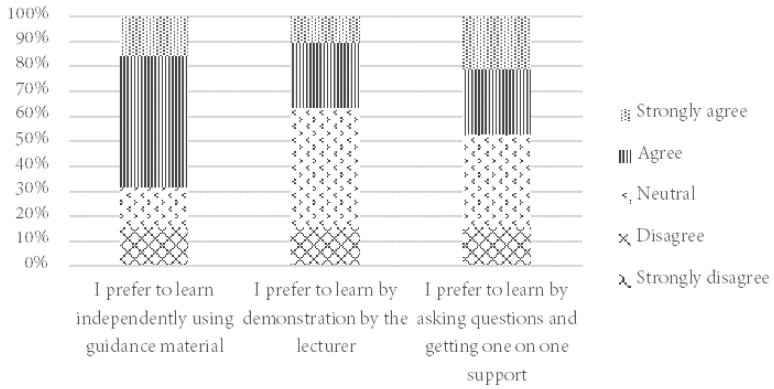

Figure 3. Mid-unit perspectives of learning preferences.

There was also positive feedback on the usefulness of videos from a revision perspective, and the ability to catch up on missed work:

> "The videos were a huge improvement; as they could be revised word-for-word whenever needed, they allowed me to have an understanding ahead of lesson."
>
> Student B response

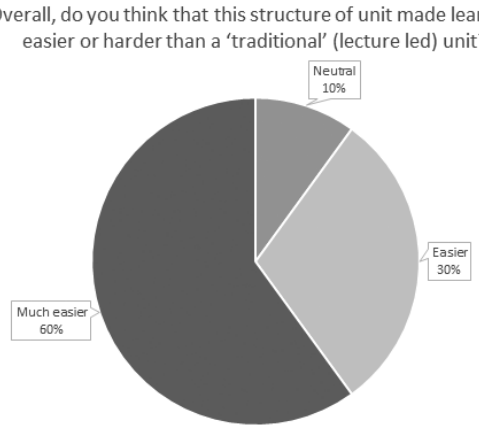

Figure 4. Perspective of unit learning.

This is in line with positive levels of engagement in other studies of flipped classroom implementation (Johnson, 2013). However, the end of unit questionnaire did identify some significant differences between the students' interaction with the theory-based and practical demonstration video elements of the module (Figure 5).

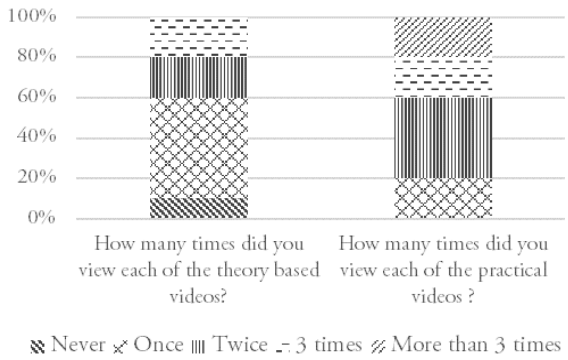

Figure 5. Viewing patterns for 'theory' and 'practical' study materials.

The students applied a very different viewing pattern to the theory-based and practical demonstration videos: 60% of students watched the theory-based videos only once or not at all, compared with 80% watching the practical videos twice or more (Figure 6). Indeed, when questioned about this in the interviews, students indicated that they interpreted the question to mean separate occasions and that they actually often viewed the practical videos several times within each session.

> "The video tutorials meant that the lecture itself could be understood in more detail and aided with notes and revision." Student C response.

In the interviews, students were asked why they were less likely to view the theory-based videos more than once. All said that they viewed these out of class and felt under less pressure to understand the contents. They suggested that there was little point revisiting the videos if they didn't understand particular points as these out-of-class elements cannot be interactive. A few students indicated that they preferred traditional lectures for this reason, with one suggesting that students prefer to be able to take their own written notes.

The students were also asked *when* they were most likely to watch the theory videos. The most popular response to this was shortly before the associated practical session, often late at night. All claimed time pressures prevented them doing it earlier, though they found it difficult to justify this. When asked *where* they were most likely to watch the videos, there was a variety of responses, though no students specifically chose a quiet environment traditionally associated with study.

Whilst it has been argued that the flipped approach enhances student engagement (e.g., Gilboy, Heinerichs, & Pazzaglia, 2015), it is also possible that some students decline to participate in flipped classroom activities if they perceive that studying alone will be equally efficient in terms of learning (White, McCollum, Bradley, Roy, Yoon, Martindale, & Worden, 2015). There was evidence of this both in the questionnaire and interviews:

> "On days that I was absent I was able to take the lesson from home exactly as I would have done in class." Student B response

When asked in interviews if access to the videos made them any more likely to miss classes all the students were quick to respond "no," but that it made them less concerned about their absence as the materials were easier to understand in isolation than a set of notes or presentation slides. Student attendance records showed no difference in attendance pattern between this module and others for the same group of students. However, all the students admitted that they were more likely to miss a theory class having viewed the video, even if they hadn't fully understood all of its contents.

Several students believe that they "learn better" doing practical applications, and this appeared to predispose them to undertaking the practical task as the starting point for their learning. Although the course was designed for them to view material in advance of the class, they were less likely to do so, preferring to watch sections as they performed tasks.

> "I learn better practically, and it made it much more easier (sic) to use UE4 than it would be if the videos weren't available." Student D response

There was a positive perception of the ability of the video materials to help students focus on the task:

> "The tutorials were really helpful and really helped me learn. I liked being able to try as I learnt." Student F response.
>
> "It's a lot more engaging, hence you are more motivated to keep focused during class-time." Student A response.

Many students claimed that use of video tutorials helped them to pace their activity to suit their rate of learning. When asked to describe a typical viewing pattern, one typical response was to watch a 30-60 second segment and then undertake that element of the practical task. Other students would watch the whole video through at the beginning of the session before repeating it in this segmented form. Around half only viewed the videos section-by-section as they completed the task. The different viewing patterns support the concept that the flipped classroom approach helps students to effectively utilise their own learning style, rather than the "one size fits all" approach of lectures. When asked if they would review the video after the session, most students (78%) said that they would do so but only when preparing work for assessment.

Feedback from the students on their experience of the unit was almost universally positive. However, there was some evidence that the students were also slow to adapt to the different pedagogy of the flipped classroom. Some students expressed a desire to be able to interact with the tutor, asking questions where necessary, like they might in a traditional classroom environment.

Grade Analysis

Grades (normalised to percentage of group) were assessed for the previous cohort, which had used a *traditional* delivery and the current cohort, which had used the *flipped* delivery. For both groups the assessment brief was identical; although there were slight differences in the game level developed for each assessment, the underlying tasks were the same, as were the assessment criteria. A summary of grade average is shown in Figure 6 (A-D are pass grades; F grades are fail).

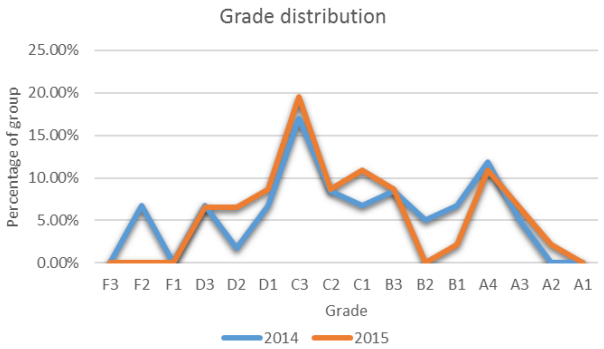

Figure 6. Grade distribution.

The overall grade point average increased from 57% (standard deviation 15.3) to 58.5% (standard deviation 12.8) from the 2014 to the 2015 cohort. However, a two-tailed t-test indicates that this difference is not significant ($p=0.66$). The overall grade performance was very similar, and there was no significant variation in the proportion of students obtaining top grades. One key area of improvement, however, was at the lower end of the scale, as under the flipped classroom model there were no fail grades, compared to 6% of the previous cohort.

Discussion

While this study echoes the results of others in terms of increased student engagement and student satisfaction, there is no evidence from this study that the use of a flipped classroom approach has a significant impact on the level of student grades, or that it enhances higher-order cognitive learning. However, it appears to have had a positive effect on the lower end of the grade spectrum by reducing the number of students failing. This may indicate that the advantages of the flipped classroom are not in an improvement of learning overall, but are based on increased engagement, the ability to self-pace and enabling students to choose their preferred approach to learning.

These advantages do not have a significant positive effect on abler students, who are able to process information at higher speed, and who therefore are also able to learn effectively from more traditional delivery patterns. However, the results suggest that the flipped classroom particularly benefits students who struggle with traditional lectures, and who may otherwise fall behind. The flipped classroom enables them to learn at their own pace, retaining motivation and enabling weaker students to achieve a pass grade, while at the same time not disadvantaging the abler students.

The study identified some issues with the use of video to deliver the important underlying theory. There is a lack of accountability for students to complete the out-of-class activities in their own time. Unlike traditional delivery methods, there is also no control over the conditions under which the students view the videos. There was some evidence that their choices may not be particularly conducive to effective learning. In many cases they were choosing to view the videos very close to the practical session, allowing very little assimilation time, which may have had an impact on the effectiveness of their learning. As the numbers of students in the study was small this is by no means conclusive, but it is an area for future consideration as the module develops.

The students were using the videos to validate their work, checking their work against that of the tutor, exhibiting a well-proven master-apprentice model that is successful in training. There was little evidence of the students testing concepts that they have developed upon reflection of their experiences, preferring simply to compare their results with those of their tutor. This suggests tactical, behaviourist learning designed to get through the work quickly, rather than the construction of deeper understanding desirable at this level.

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