Using Learning Analytics to Evaluate the Effectiveness of the Flipped Classroom Approach

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Structured Abstract

BACKGROUND
The *Flipped Classroom* seems to have been embraced globally as the latest solution to quality engineering education. Higher education institutions everywhere are extolling the benefits of this "new" innovative teaching method with many of apparently them scrambling to get on board at all costs. While the rationale for using a flipped classroom approach seems sound and reasonable, there appears to be a distinct lack of evidence showing that this new teaching and learning approach is any better than other quality teaching practices.

PURPOSE
The main focus of the current study was to attempt to quantify the effects that the flipped classroom approach had on the performance of students on their course assessment tasks.

DESIGN/METHOD
In this study, the flipped classroom approach was introduced for the first time to students in a second year engineering Fluid Mechanics course to try to improve student motivation and engagement, and to improve cognition and understanding of the course material. Students worked through narrated, online eLectures (recorded on Mediasite) prior to attending face-to-face class (workshop) sessions. It was hypothesised that the more time students spent working through the weekly eLecture material, the better their results would be for the course assessment items. Learning analytics was used to investigate this hypothesis. Student viewing data collected by Mediasite was analysed to determine whether there was a correlation between the total amount of time students spent on the weekly eLectures and their results for three of the summative course assessment tasks.

RESULTS
The study found a poor correlation (R^2=0.0498, PCC = 0.2232) between the time students spent on eLectures and the correctness of their answers to the weekly quiz questions. The correlations between eLecture time and final exam mark were equally low (R^2 = 0.0688, PCC = 0.2623).

CONCLUSIONS
It was proposed that the poor correlation between the time students spent on eLectures and the correctness of their answers to the weekly quiz questions may have been the result of students rushing through the eLecture material and questions “just in time” in order not to miss out on marks and to get up to speed before the workshops. However, there was no real evidence to confirm this hypothesis. It was suggested that flipped learning may only be more effective than traditional teaching practices if students work through, learn and understand the pre-lecture material properly. Student feedback on the flipped classroom method was overwhelmingly positive and clearly demonstrated that students enjoyed and embraced the new teaching and learning approach. However, this did not appear to translate into significant improvements in student cognition or deeper learning. Although the results of this initial study are generally inconclusive, and do not clearly either confirm or refute whether the flipped classroom approach was any more successful than traditional teaching approaches, the study has clearly demonstrated the intrinsic value of learning analytics as a tool to monitor student learning. While this initial study has produced some interesting and thought-provoking results, there can be many factors that influence performance and results from one student cohort to the next and these would have to be taken into account to enable more tangible conclusions.

KEYWORDS
Flipped classroom, learning analytics, classroom response systems, Mediasite

Introduction

The *Flipped Classroom* seems to have been embraced globally as the latest solution to quality engineering education. Higher education institutions everywhere are extolling the benefits of this "new" innovative teaching method with many of them apparently scrambling to get on board at all costs. It appears that some institutions have even chosen to adopt the flipped learning approach for all of their engineering programs. While the rationale for using a flipped classroom approach seems sound and reasonable, there appears to be a distinct lack of evidence showing that this new teaching and learning approach is any better than other quality teaching practices.

In this study, the flipped classroom approach was introduced for the first time to students in a second year engineering Fluid Mechanics course (n=66). The flipped classroom approach was implemented in order to try to improve student motivation and engagement, and to improve cognition and understanding of the course material. To promote more student engagement, and to improve student participation and interaction, a new type of classroom response system (CRS) called Learning Catalytics (LC - https://learningcatalytics.com/) was also trialled in the class. The CRS allowed students to use their mobile devices (phones, tablets, laptops) to respond to a variety of numerical, multiple-choice, short-answer and open-ended discussion questions posed both before class and during the face-to-face workshop sessions.

The main focus of the current study was to try to quantify the effects that the flipped classroom approach had on students' assessment task performance. The study used learning analytics to investigate whether there was any direct correlation between the amount of time students spent studying the weekly online material and the correctness of their answers to the weekly pre-lecture and workshop questions, as well as on their final exam marks. This paper presents the initial results of the study.

Flipped Learning

The Flipped Classroom is a pedagogical model in which the typical lecture and homework elements of a course are reversed (Diaz et al., 2013). Although there is no exclusive model for the flipped classroom, it has generally become known as the practice of providing students with pre-recorded lectures before class and then using the classroom time to engage the students in learning activities to build on the knowledge gained from the pre-recorded lectures.

Flipping allows for an instructor to provide traditional, low cognitive level, lecture materials in an alternative format outside the classroom, freeing up class time normally used to 'convey' information to students (Toto & Nguyen, 2009). Instruction that used to occur in class can then be accessed in advance of class (generally at home) so that students are well prepared and can derive the most benefit from the time spent in the face-to-face learning environment (Tucker, 2012). Toto and Nguyen (2009) maintain that flipping lectures retains the best qualities of the traditional teacher-centred lecture model while also including the best qualities of the active learning or student-centred teaching model.

In the current study, students worked through narrated, online lecture material (eLectures) prior to attending face-to-face class (workshop) sessions. The eLectures were developed using Mediasite (http://www.sonicfoundry.com/mediasite) and students would access these each week through the learning management system (LMS - Blackboard). The workshop sessions were then used to foster student engagement by working through typical problems, providing feedback, introducing advanced concepts, and facilitating student discussions and other collaborative learning activities (Toto & Nguyen, 2009; Tucker, 2012).

The eLectures were made generally available to the students at least one week before the workshop sessions. This allowed students to work through and study the eLectures when

and where they wanted, and for as long as they wanted. Different students learn at different rates and this arrangement allowed them to spend as much time on the material as the needed. All students need time to be able to absorb and process the information needed before it can be applied (Toto & Nguyen, 2009).

Research has shown that students typically lose interest in online material after about six minutes (Fowler, 2013). Therefore, in order to reduce the length of time that students were required to spend online in each sitting, a number of “mini” eLectures were developed and uploaded to Mediasite each week. Each of these mini eLectures generally dealt with a single topic that the students would work through before the workshop. The eLectures would explain the theory, demonstrate a few worked examples using the theory, and then pose a question or two for the students to solve themselves. The students solved the questions and then submitted their answers on the LC website using their home computer or mobile devices (phones, tablets, laptops etc). LC provided students with instant feedback on their CRS answers so they could see how they were going before moving on to the next eLecture.

In order to encourage students to utilise and engage with the eLectures, the student questions were graded. The weekly eLecture questions were worth up to 15% of the final grade. Students could submit their answers to the eLecture questions online, using a PC, laptop or Smartphone, or by SMS if these were not available. The eLecture questions were disabled two hours before the workshop sessions were scheduled to commence.

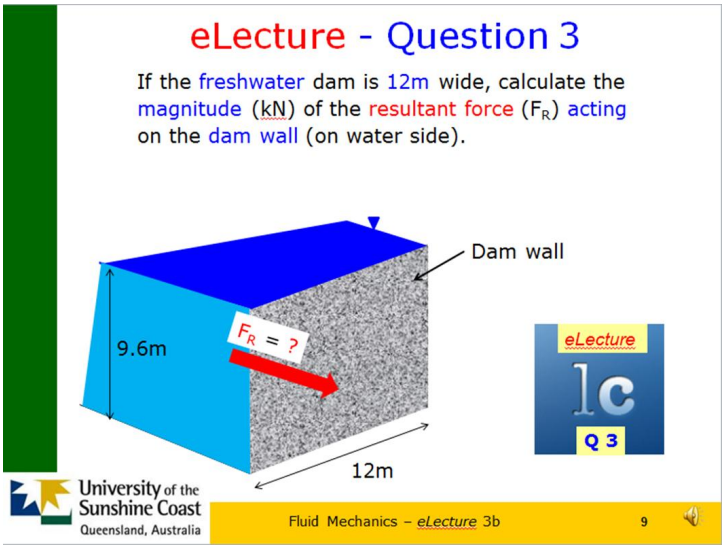

Figure 1 - Typical eLecture question

Workshops extended the eLecture content by including a variety of carefully designed, engaging activities (many were group activities) that used CRS questions to facilitate discussions, problem solving and case study analysis to enhance student cognition. Students used their mobile devices to respond to the CRS questions posed during the workshops. This arrangement also provided opportunities to identify potential problem areas, and to enable ongoing assessment and evaluation of learning outcomes. To encourage participation in the workshops, students were also graded on the correctness of their responses to the CRS questions. A maximum of 25% of the total student grade was allocated for this.

The CRS was also used at various times throughout the semester to survey students and obtain feedback on their experiences and feelings about the new flipped classroom teaching method. Feedback was also received via the University’s normal end of semester student feedback on teaching and courses (SETAC) course evaluation instruments. The student feedback obtained through these processes provided valuable and useful insight into student perceptions of the flipped learning approach.

Learning Analytics

Learning analytics has been defined as “the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs” (Brown, 2012). While there are various ways to collect student learning data, the university LMS is often one of the main sources used to collect quantitative data on student learning behaviour. LMS often have built-in statistics functions that can provide valuable information on student learning activities. However, it is important to recognise that the data collected from LMS can be quite subjective and not all data collected can be automatically used as a measure of student learning. For example, just because a student may have logged on to the LMS, this does not necessarily mean that they were engaged in meaningful learning activities. Therefore, when using learning analytics on information collected from LMS systems as an indicator of student performance, or as a measure of student learning, it is important to carefully select only relevant data. As in any analytics initiative, the selection of data directly affects the accuracy of the predictions and the validity of the analysis (Brown, 2012).

In order to measure the impact and value of the eLectures, and to improve the accuracy of the data collection and statistical analysis of students’ learning behaviour while working through eLectures, they were recorded and accessed through Mediasite. Using Mediasite allowed precise tracking of each student’s viewing activity for each eLecture throughout the course. The collected data could be presented using a variety of interactive graphs, intensity maps or playback statistics. This study used a number of useful Mediasite functions including:

- A “Who’s Watching Now” dashboard that gave a real-time snapshot of which students are viewing each of the eLectures;
- eLecture analytics that showed which content was being watched, when and by whom during any given time period. Intensity maps also indicated which presentation segments were being watched most often; and
- User analytics showed a specific student’s (or group of students) viewing habits over any given time period, including presentations watched, viewing activity and total viewing durations.

All of the data generated by Mediasite could be exported to EXCEL or other programs for deeper analysis through other applications and tools.

Methodology

This study used learning analytics to investigate how effective the flipped classroom approach was in producing desired student learning outcomes in a second year fluid mechanics course. The study analysed data collected by Mediasite (through the University's LMS) to determine whether there was a correlation between the total amount of time students spent on the weekly eLectures and their results for three of the summative course assessment tasks. The three assessment tasks used in the study to measure student performance were the correctness of their answers to the weekly eLectures and Workshop CRS questions (15% + 25% = 40% of final grade), and their results in the final exam (20%).

Previous research (McKay et al., 2012) concluded that a student's grade point average (GPA) is a reliable predictor of their assessment task performance. This conclusion was also tested in this study using learning analytics by comparing the students' GPAs (max 7.0) to their final exam result. The study also used learning analytics to investigate whether there was any direct correlation between:

- the amount of time students spent studying the weekly online material;
- the correctness of their answers to the weekly eLecture and CRS questions; and
- students' final exam results.

The data were analysed using both linear regression and Pearson product-moment correlation coefficient (PCC) techniques. Although PCC analysis is generally the more widely used way of measuring the degree of linear dependence between two variables, linear regression plots were used here to present the data comparisons in a way that is easier to visualise. The linear regression plots are presented as Figures 2 to 4 as listed in Table 1. The results of the PCC analysis are included in the respective figure captions.

Table 1: Study Learning Analytics Comparisons

Compare	With	Figure
Student GPA at start of semester	Student Final Exam Mark (/20)	Figure 2
Amount of time spent studying the weekly online material (eLecture Hours)	Correctness of answers to the weekly eLecture and workshop CRS questions (/40)	Figure 3
Amount of time spent studying the weekly online material before final exam	Final exam result (Final Exam)	Figure 4

Results

The plots of the comparisons listed in Table 1 are presented in the following section.

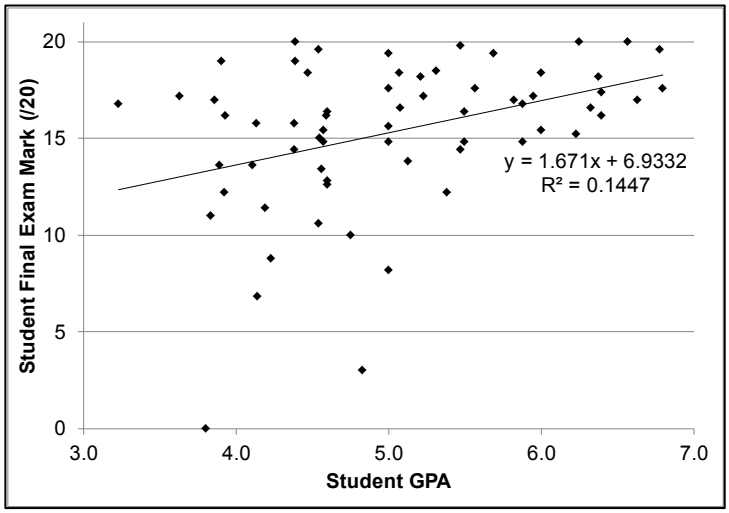

Figure 2 - Comparison of student GPA with final exam mark (PCC = 0.3804)

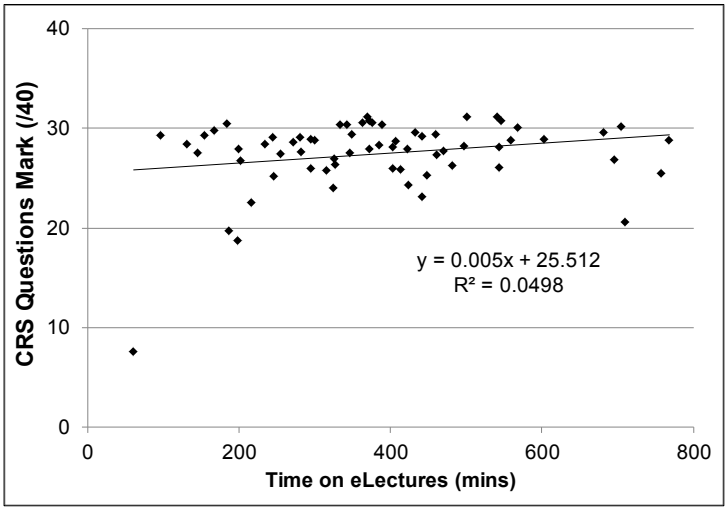

Figure 3 - Comparison of time spent on eLectures with CRS question results (PCC = 0.2232)

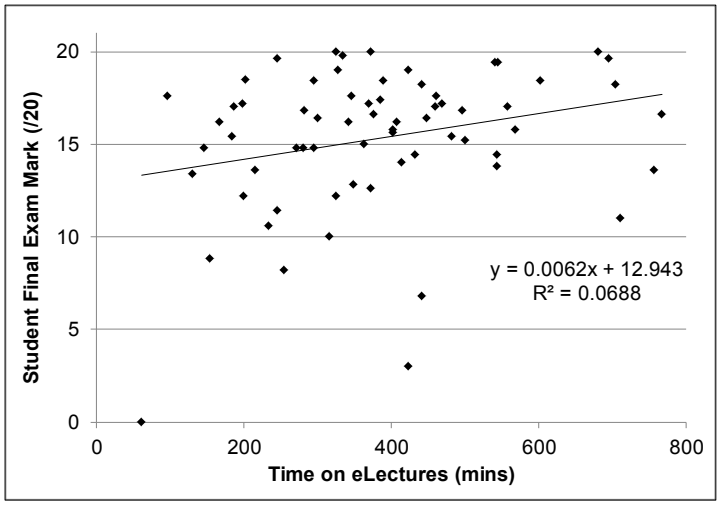

Figure 4 - Comparison of time on eLectures with final exam results (PCC = 0.2623)

Student feedback on the new flipped classroom teaching method was solicited at various times throughout the semester for evaluation purposes. Table 2 lists one of the CRS evaluation questions and the student responses for that question. Table 3 lists a small sample of student SETAC responses to one of the open-ended feedback questions.

Table 2: Student responses (n=64) to one CRS evaluation questions

Question: Do you like or do you not like being able to work through the eLecture material whenever it suits you?	
I like it a lot!	78%
I like it a little!	20%
I dislike it a lot!	2%
I dislike it a little!	0%

Table 3: Sample of student open-ended SETAC responses

Q3.1) Aspects which were done well and which should be continued
I really enjoyed the LC part of the course. It enabled me to go ahead and review the lecture content more than once to help reinforce what was being taught. And each week's lectures gave a good foundation to the workshops where that knowledge could then be expanded upon.
LC was a great method of learning at your own pace at home. It also makes you learn the course content each week, and then by applying it the next day it cements the knowledge learnt.
Really enjoyed the eLectures and online assessments... They really helped me gain a full understanding of subject material
The short online lectures (eLectures) each week were very beneficial and I found them to be much more useful then a standard lecture.
The way the course was delivered was excellent. I particularly liked the eLectures and subsequent question format, which I think really helped me understand fluid mechanics.
eLectures are very helpful and an excellent way of learning the material (It is not possible to pause or rewind an actual lecture).
The whole course outline was perfect. This is the way i would like all my subjects to be taught. No more boring lecture, finally a way that keeps my engaged and wanting to learn. Really enjoyed the working style wouldn't change a thing.

Discussion

A number of studies (McKay et al., 2012; Elliot et al., 1999; Harackiewicz et al., 2002) have demonstrated that a student's performance in previous courses can be a fairly reliable predictor of future course performance. Most universities use some type of grade point average (GPA) ranking to measure student performance. Figure 2 compares the GPAs of the study students before starting the Fluid Mechanics course (maximum possible GPA score = 7.0), with their results in the final exam. The linear regression coefficient of determination value (R^2) of 0.1447, and PCC value of 0.3804, show a relatively low correlation between the students' final exam results and GPAs in this study. This correlation is not as strong as has been demonstrated in previous research. However, there can be many factors that influence performance and results from one student cohort to the next and these would have to be taken into account to enable a more accurate and realistic conclusion. Although, this comparison did demonstrate the highest correlation values of the three comparisons made in this study.

All of the learning materials for the course were presented to students via the weekly narrated Mediasite eLectures. Mediasite allowed precise statistical data collection and analysis of students learning behaviour while working through the eLectures. Mediasite produced a detailed record of how many times a particular eLecture was viewed by students and exactly when and how many times it was accessed. It was hypothesised that the more time students spent working through the weekly eLecture material, the better their responses would be to the weekly eLecture and workshop CRS questions. However, Figure 3 shows a relatively poor correlation (R^2 = 0.0498, PCC = 0.2232) between the time students spent studying the eLecture material and the correctness of their answers to the weekly CRS questions.

The low result shown in Figure 3 was surprising as it was anticipated that students' cognition and recollection levels would be much higher directly after learning each week's material and that this would be clearly demonstrated in the degree of correctness of student's answers to the CRS questions. However, this was not the case and the low correlations may be evidence that some students rushed through the eLecture material and questions "just in time" in order not to miss out on the chance of getting at least some of the marks allocated for the eLecture CRS questions. The Mediasite reports showed that the peak viewing activity for the eLectures always occurred on the day before the workshop (i.e. the day before the eLecture questions were disabled) further reinforcing this possibility. This may be a significant finding relating to the efficacy of the flipped classroom approach.

Research has shown that all students need enough time to be able to absorb and process information before they can apply it (Toto & Nguyen, 2009). While providing students with learning materials and enough time to work through and absorb it before lectures is a good idea in theory, if students do not use the learning time wisely, then it may be no more effective than traditional teaching practices. In fact, it could potentially be worse for students if they rush through the materials the night before the lecture just to get up to speed as this could result in only superficial learning occurring (Marton & Säljö, 1976; Biggs, 1987). Therefore, flipped learning may only be more effective than traditional teaching practices if students actually use the available time before lectures effectively to work through the pre-lecture material in order to fully learn it and understand it properly.

In order to evaluate whether the total amount of time spent on the eLecture materials affected student performance in the final exam, these variables were also compared. Again it was hypothesised that the more time students spent studying the weekly eLecture material, the better their performance would be on their final exams. Figure 4 shows poor correlation (R^2 = 0.0688, PCC = 0.2623) between the total time (up to Week 13) students spent studying the eLecture material and the correctness of their final exam questions (held in Week 13). These results were also unexpected and potentially disappointing with respect to the efficacy of flipped learning. However, further research is needed to investigate this in more detail.

Student feedback on the flipped learning method was overwhelmingly positive and Tables 2 and 3 clearly demonstrate how much students enjoyed the new teaching and learning approach. However, while it was evident that students embraced and successfully engaged with the flipped learning approach, this did not appear to translate into significant improvements in student cognition or deeper learning (Marton & Säljö, 1976) as discussed above. Although the final student grades for this cohort were slightly higher than previous years, this was thought to be a result of the unusually high marks allocated the CRS assessment questions (40% of final grade). Students often worked in groups to solve these questions and this probably increased the collective average student grades. New weightings for the course assessment items will be introduced in future.

While this initial study has produced some interesting and thought-provoking results, it must be recognised that these results must be viewed in their proper context. Statistical data collected through online monitoring software can be inherently variable and unreliable in nature, so any conclusions drawn from analysis of this data must be viewed correspondingly. Although the results of this initial study are generally inconclusive, and do not clearly either confirm or refute whether the Flipped Classroom approach was any more successful than traditional teaching approaches, the study has clearly demonstrated the intrinsic value of learning analytics as a tool to monitor student learning behaviour. The study also clearly demonstrated how much students enjoyed and embraced the flipped classroom teaching and learning approach.

Building on the experience gained and the lessons learned from this initial study, the second stage of the research has now commenced. Further results from the study will be released as they become available.

Conclusions

This paper used learning analytics to investigate whether the flipped classroom approach used in a second year fluid mechanics class was any more successful than using a traditional teaching approach. It was hypothesised that the more time students spent working through the weekly eLecture material, the better their responses would be to the weekly CRS questions. However, the study found a relatively poor correlation (R^2=0.0498, PCC = 0.2232) between these two variables. The correlations between eLecture time and final exam mark were equally low (R^2 = 0.0688, PCC = 0.2623).

It was hypothesized that these poor results may have been the result of students rushing through the eLecture material and questions “just in time” in order not to miss out on marks and to get up to speed before the lecture. However, there was no real evidence to confirm this hypothesis. It was suggested that flipped learning may only be more effective than traditional teaching practices if students work through, learn and understand the pre-lecture material properly. Student feedback on the flipped classroom method was overwhelmingly positive and clearly demonstrated that students enjoyed and embraced the new teaching and learning approach. However, this did not appear to translate into significant improvements in student cognition or deeper learning.

Although the results of this initial study are generally inconclusive, and do not clearly either confirm or refute whether the Flipped Classroom approach was any more successful than traditional teaching approaches, the study has clearly demonstrated the intrinsic value of learning analytics as a tool to monitor and predict student performance and learning. While this initial study has produced some interesting and thought-provoking results, it must be recognised that these results must be viewed in their proper context. Statistical data collected online can be inherently variable and unreliable in nature, so any conclusions drawn from analysis of this data must be viewed correspondingly. In addition, there can be many factors that influence performance and results from one student cohort to the next and these would have to be taken into account to enable more accurate conclusions.

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