Lessons from Flipping Subjects in Engineering: Effectiveness of Student Learning in a Flipped Environment at the University Level

Ryan Hoult, Ph.D.; Murray Peel, Ph.D.; and Colin Duffield, Ph.D.

Abstract: This paper outlines the subjective and quantitative outcomes of the introduction of the flipped classroom approach to two engineering subjects at the University of Melbourne. In this approach, lectures are delivered online as opposed to the traditional method of being provided in person. To facilitate learning, after each part of an online lecture, students completed an activity to reflect upon and review the content via compulsory questionnaires. Students would then attend formal classes in person (e.g., workshops) in which they would participate in interactive and collaborative activities related to the online lecture material. Surveys were provided to the students at the beginning of the semester to understand their perceptions of different learning activities. The surveys indicate that students who did well on the questionnaires also did well in the subject with a positive trend between questionnaire scores and final grades in both subjects. The survey results suggest that the flipped classroom method could provide students with better learning outcomes for subjects at the university level if implemented in a way that promotes active and student-centered learning. Some recommendations are provided based on the results of this paper for the implementation of the flipped classroom method for future subjects at the university level. DOI: 10.1061/(ASCE)EI.2643-9115.0000028, © 2020 American Society of Civil Engineers.

Introduction

The effectiveness of traditional approaches to teaching at the university level is being challenged because the increased accessibility to the internet better accommodates access to learning materials over several forms of media. Typically, traditional methods of teaching at the university level are structured with a number of face-to-face lectures and a weekly workshop (i.e., a small class size of 30–40 students actively participating in groups) (Butt 2014). However, some evidence suggests that providing face-to-face lectures may not be the most effective way of teaching (Berrett 2012; Bishop and Verleger 2013; Chickering and Gamson 1987; Kim et al. 2014; Strayer 2012). Students born in recent decades have grown up alongside developing technologies and information platforms, altering the way that these students think and process information in comparison to their predecessors who were taught traditionally (Prensky 2001; Roehl et al. 2013). As such, further consideration is required to determine the relative shortcomings in traditional teaching methods.

A flipped classroom model is an alternative teaching platform (Baker 2000; Lage et al. 2000). Although there is a lack of consensus on the definition of a flipped classroom (Bishop and Verleger 2013), some consider the simplest definition to be that given by Lage et al. (2000): “Inverting the classroom means that events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa”. Bishop and Verleger (2013) suggest a two-part definition is required to define the flipped classroom as an educational technique: “interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom”. Although a plethora of other definitions of the flipped classroom can be found in the literature (Baker 2000; Bergmann et al. 2011; Davies et al. 2013; Foerstch et al. 2002; Fulton 2012; Hughes 2012; Talbert 2012; Zappe et al. 2009), the basic concept is to provide students with online content and video lectures before attending in-class workshops in which students then participate in interactive activities that are typically undertaken in groups. This method of delivering content can allow students to utilize the time in class to advance concepts, solve problems, and engage in a collaborative environment (Tucker 2012).

As summarized in Kim et al. (2014), there are at least three primary benefits to implementing the flipped classroom method: (1) online lectures allow students to allocate their time better and watch lectures at their own pace, (2) students have a better opportunity for active, interactive, and collaborative activities during the face-to-face class time, and (3) more in-class time can be committed by teaching staff, which can help to provide feedback and monitor student performance. Replacing in-class time from lectures with activities such as workshops can increase student engagement, interactivity, and collaborative learning, which ultimately improves learning outcomes (Flores et al. 2016; Foldnes 2016; Koo et al. 2016; Wanner and Palmer 2015).

As explained in Mojtabehi et al., (2020), to successfully implement the flipped classroom, academics must (1) consider designing a model that effectively integrates appropriate technologies with instructional strategies (Missildine et al. 2013), (2) manage the expectations of students who are comfortable with the traditional model through the integration of old and new techniques, (3) consider the nature of knowledge and theories being disseminated and also the context of the discipline in designing the alternative model through the integration of old and new techniques, (3) consider the nature of knowledge and theories being disseminated and also the context of the discipline in designing the alternative model through the integration of old and new techniques, (3) consider the nature of knowledge and theories being disseminated and also the context of the discipline in designing the alternative model through the integration of old and new techniques, (3) consider the nature of knowledge and theories being disseminated and also the context of the discipline in designing the alternative
models, and (4) provide appropriately sized spaces for active learning to ensure integration of the flipped classroom.

Several studies have shown the flipped classroom approach to be effective in teaching engineering students. Hotle and Garrow (2016) studied the effectiveness of the flipped classroom when applied to two sections of an undergraduate course in civil engineering systems, with one of the findings indicating that students initially struggled with the format of the flipped classroom. Li and Daher (2017) implemented a flipped learning module in a traditional water resources engineering class and found an increase in student performance in comparison to the traditional approach. Gross and Musselman (2018) flipped several junior- and senior-level structural design courses at the university level and found that questionnaires were an effective tool that encouraged students to engage with the conceptual material and could be used as a formative assessment tool. More recently, Ling and Gan (2020) conducted a study on more than 200 sophomores majoring in construction engineering and management and found that the preclass online video lectures gave students the flexibility to study at any time and place, with the in-class activities being actively used to discuss more complex problems. Furthermore, Mojahedi et al. (2020) found that the preclass activities were an important feature of the flipped classroom in enabling active engagement for students.

Although there have been some contributions to research on the flipped classroom methods in recent decades, there is still an overall limited amount of scholarly research on the effectiveness of flipping the classroom (Bishop and Verleger 2013). Furthermore, the qualitative and quantitative research that does exist can be contradictory. For example, Zappe et al. (2009) found that students perceived a flipped undergraduate engineering class to have a positive input on their learning. However, other research suggests that there was no significant difference in performance between students enrolled in the traditional classroom and the flipped classroom (Davies et al. 2013; Strayer 2012). Moreover, most studies, such as that by Kim et al. (2014), have relied upon students’ perceptions to evaluate the quality of the teaching model and the student learning experience. Further research is evidently required to determine the effectiveness of flipped classrooms.

The University of Melbourne (UoM) offers two primary paths into a Master of Engineering degree with professional accreditation: a Bachelor of Design and a Bachelor of Science. The Bachelor of Design provides students with an exclusive skill set related to a wide range of contexts such as buildings, transport, infrastructure, and urban planning. The Bachelor of Science allows some flexibility and the opportunity for students to study engineering in a wider scientific context. As part of these two bachelor programs majoring in civil systems, two core subjects are typically undertaken by students in their second and third year, which are the primary focus of this paper: Earth Processes for Engineering (denoted as CVEN30008) and Engineering Risk Analysis (denoted as ENEN20002). ENEN20002 introduces students to physical earth processes and their engineering applications and implications, primarily concentrating on the engineering aspects of climate, water, and soils and their interactions and CVEN30008 focuses on how risk analysis and management principles and techniques can be applied to engineering projects. These subjects are typically only delivered in one (of two) semesters per year. However, due to the recent significant increase in enrollment for these core subjects (i.e., required subjects for students in civil systems), in 2018 it was decided to offer these subjects in both semesters. This gave the authors an opportunity to flip these subjects for one of the two semesters. This meant that the passive and didactic delivery of lectures in the traditional semester would instead be provided in an online environment and complimented with other engaging activities. This is consistent with the literature as one of the primary reasons for implementing the flipped classroom approach appears to be due to the difficulties in accommodating growth and student demand given the limited capacity of university campuses (Baeppler et al. 2014).

This paper investigates the effectiveness of student learning in a flipped environment for the two subjects described previously (ENEN20002 and CVEN30008) by analyzing several sources of data. Based on the results, this paper ultimately provides some guidance and recommendations to universities in implementing the flipped model. Although this paper investigates the effectiveness of flipping two specific engineering subjects, it is expected that the research outcomes and recommendations can be extended to other areas of teaching.

Methodology

As stated in the Introduction, this paper focuses on quantifying the effectiveness of learning in a flipped environment at the university level. Two subjects were the focus of this paper at the Department of Infrastructure Engineering at the University of Melbourne: Earth Processes for Engineering (ENEN20002) and Engineering Risk Analysis (CVEN30008). This section provides an overview of the methodology undertaken to flip these subjects, as well as the different sources of data that are used to assess the effectiveness of learning.

Both subjects had what some would consider standard teaching time commitments as given in Table 1. ENEN20002 typically had 3 h of lectures and a 1-h workshop each week and CVEN30008 typically had 2 h of lectures and a 1-h workshop each week. The traditional lecture is defined in this paper as a formal presentation conducted by a lecturer to the entire student body enrolled in the subject, whereas a workshop is defined as a smaller class allowing for discussions of lecturer content and assignments. The workshops also provide some interactive or hands-on learning, typically with collaborative group exercises. Two UoM lecturers primarily deliver the content for ENEN20002, whereas one UoM lecturer and several industry guest lecturers deliver the content for CVEN30008. At the UoM, two semesters are provided each academic year, typically running from late February until late November. Each semester consists of twelve weeks of teaching. In 2018, Semester 1 of ENEN20002 was taught using a flipped method with 133 enrolled students and Semester 2 was taught using a traditional method with 128 enrolled students. For the same year, Semester 1 of CVEN30008 was taught using a traditional method with 421 enrolled students and Semester 2 was taught using a flipped method with 136 enrolled students.

YouTube Analytics

For the flipped streams of the subjects, the total teaching time arrangements were maintained (i.e., the same amount of lecture and workshop hours were used for both the flipped streams and the traditional stream). The students in the flipped streams were provided

<p>| Table 1. Summary of subjects, contact hours, and number of enrolled students for 2018 |
|-----------------|-------------------|-------------------|-------------------|</p>
<table>
<thead>
<tr>
<th>Subject</th>
<th>Lectures (h/week)</th>
<th>Workshops (h/week)</th>
<th>No. of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENEN20002</td>
<td>3</td>
<td>1</td>
<td>128</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>133</td>
</tr>
<tr>
<td>CVEN30008</td>
<td>2</td>
<td>1</td>
<td>421</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>136</td>
</tr>
</tbody>
</table>

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online videos for the lectures embedded in the online learning platform referred to as the learning management system (LMS). A total of 35 and 16 lectures were provided online as videos in the flipped versions of ENEN20002 and CVEN30008, respectively. There were fewer online lectures for CVEN30008, because the guest lectures provided by industry representatives were delivered in person. A 1-h (optional) in-person tutorial would be provided by a UoM lecturer at the end of each week. The session is identified as a tutorial, as opposed to a lecture, as it is meant to provide an opportunity for students to ask any questions related to the online (video) lectures for that week. The online lecture videos were compiled from the lecture capture system (i.e., screen video capture series) of the traditional semester prior to the flipped semester. In this way, the online videos were no different from what students could access in typical UoM subjects through lecture capture. However, the online lecture videos in the flipped stream were split into three separate parts (i.e., Part 1, Part 2, and Part 3) approximately 10–15 min in length based on recent research which suggests a limit of 15 min in length for an online video lecture (Gross and Musselman 2018; Li and Daher 2017; Wilson and Korn 2007). Furthermore, as explained in Biggs and Tang (2011) and Bligh (1972), the attention of students in the didactic, traditional lecture is only maintained for approximately 10–15 min (Fig. 1), after which learning can drop off rapidly. Splitting the videos into three separate parts allowed for what is called a change in activity. A questionnaire followed each video part, which would be required to be undertaken before the student would be allowed to watch the next part of the lecture series. The quiz provided the short rest and change in activity that is required to restore performance to (almost) the initial level of effective learning (Biggs and Tang 2011), shown in Fig. 1. The questionnaires also allowed students to reflect on and review each different part of the learning outcomes for each lecture. Recent research has suggested that preworkshop activities, such as the online quizzes used in this paper, are a significant component of the flipped classroom, as they allow students to be actively engaged in independent learning and help construct their knowledge (Mojtahedi et al. 2020).

The online videos and corresponding questionnaires (discussed in more detail in the subsequent section) for each week were expected to have been completed by each student before attending the workshop for the week that followed (i.e., the students were expected to attend the lectures for Week 1 before attending the workshop in Week 2). This is because the content for each week was subsequently used within the workshop for the week that followed. The 1-h workshop each week was the primary in-class component for the flipped stream of these subjects, in which students would collaborate in group activities, interactively applying the theories and knowledge learned from the activities undertaken out-of-class the week before (i.e., online lectures and questionnaires). However, students could technically complete the out-of-class activities the same day, before arriving at their designated in-class workshop time each week.

The videos were uploaded to the platform YouTube, in which they were unlisted (i.e., unable to be found via a search engine) and embedded into the LMS. This platform allowed the authors to conduct a statistical analysis at the end of the semester with YouTube Analytics, which was not possible had the videos been individually uploaded to the LMS.

**Questionnaires**

As previously stated, a questionnaire was provided after each part of the online lecture in the flipped stream of the subject. The quiz was required as sequential lectures and corresponding material would not become available, nor would be visible, in the LMS unless the quiz was completed. This procedure is shown in Fig. 2.
QUESTION 1
The Solar Declination is defined as the angle between the vertical at the Equator and the Sun at solar noon.

True
False

QUESTION 2
The Solar Zenith angle is the angle between the ______ and the ______ at ______.

Calculate the solar zenith angle for the case where:
Declination = 15° north, Longitude = 142° west and Latitude = 32° south.

Fig. 3. Example of questions used for a lecture in ENEN20002.

For example, Lecture 1, Part 1 (video) and the corresponding quiz for Lecture 1, Part 1 is discoverable by student X in the LMS. However, Lecture 1, Part 2 (video) and the corresponding quiz is hidden until the quiz for Lecture 1, Part 1 is undertaken by student X. Although the quiz was compulsory, only an attempt needed to be made by the student in order to see the content that followed. Allowing the content to be either hidden or discoverable was made possible through the LMS with the adaptive release function (Fig. 2). Once the video and content were released (i.e., made discoverable) to the student it remained accessible for the semester.

Each quiz ranged anywhere from one to seven questions. Each question was of one of the following types: multiple choice, true or false, calculated numerical, fill in the blank, or match the question with the answer. The number of questions per type for each quiz was dependent on the complexity of the content delivered in the corresponding 10- to 15-min video, as determined by the coordinator of the subject. An example of some of the types of questions is shown in Fig. 3. The LMS provided statistics for each quiz and individual question, such as the number of completed attempts and average score. The results of the questionnaires also helped frame discussions with the students in the (optional) 1-h tutorial provided at the end of each week.

Surveys
A survey was provided at the beginning of the semester to students enrolled in the flipped stream of the two subjects. The survey is similar to that provided to students in the research conducted by Butt (2014). Student information such as name, student number, gender, and whether the student was a local student, was collected. A nonlocal student would correspond to an international or exchange student. Furthermore, the survey asked the students to rank a few university-based activities intended to facilitate learning. These surveys were part of an ethics approved research investigation at UoM (Ethics ID Number 1750529.1). A plain language statement about the research that was being conducted was provided to all students enrolled in the subject before the semester began, which emphasized that no personal identifying information of participants would be published. The feedback forms were optional, which was also heavily emphasized to all of the students, and not completing the form corresponded to the student opting out of the research project. The survey was administered to the students in person by one of the authors at the start of the semester of each subject during the workshop. The plain language statement (PLS) and the survey are presented in Appendix I.

The survey asked students to rank the degree (a lot, some, or least) they felt they learned from (1) reading, text, graphs, etc., (2) listening to someone talk, and (3) performing an activity. Students were also asked to assign the same rankings of a lot, some, or least to indicate how they felt they learned from (1) lectures, (2) tutorials, (3) individual study, and (4) group study. The complete survey is presented in Appendix II.

Subject Experience Surveys
Subject experience surveys (SES) were also collected which sought students’ experiences and perceptions of learning. The SES was anonymous and completed online by the students at the end of the semester and before their final assessment (i.e., exam). Although completing the SES by the students was not compulsory, it offered students the opportunity to provide feedback on their learning with the aim of improving the quality of subject offerings and teaching. The student comments in the SES are considered valuable in the advancement and improvement of teaching methods, and aid in creating a positive flipped classroom experience. The number of students that provided feedback through the SES for the flipped streams of ENEN20002 and CVEN30008 was 58 (44%) and 76 (56%), respectively. Some of this feedback will be provided in subsequent sections.

Data Analysis
The subsequent sections analyze the three data collection methods [online lecture data (i.e., YouTube Analytics), quiz results, and surveys] that were used for each subject and include some of the student feedback obtained from the SES.

Lecture Attendance
Data was extracted from YouTube Analytics for ENEN20002 and CVEN30008. Of importance was information on the daily number of views (n_v) and the average percentage viewed (\(v_{avg}\)). Unfortunately, it was impossible to extract individual views and the corresponding individual view duration. Moreover, it was impossible to detect if the same person viewed a video more than once and whether the person had watched the video or if it played unattended. Thus, lecture attendance is simply defined as the number of times the video was started by someone. To calculate an approximate lecture attendance, Eq. (1) was used, which takes the sum of the number of views per day multiplied by the average
percentage of video viewed for that day. For the total lecture attendance (TLA), the sum of all of the days of the semester, including the study without teaching vacation (SWOTVAC) period, can be considered. If the weekly lecture attendance (WTA) is warranted, the sum of the number of days of the week the lecture video is released online would only be considered (i.e., WTA for Week 3, Lecture 1, Part 1 would only consider the Sunday to the Saturday of Week 3 of the semester)

\[ \text{Attendance} = \sum_{i=1}^{n} n_{di} v_{avg}\]  

(1)

where \( i = \) a given day, and \( n = \) last day considered.

Using Eq. (1), the TLA and WLA were calculated for both subjects as a function of the number of lectures \((L_n)\) and the number of weeks \((w)\) in the semester. The subsequent two sections present the findings of lecture attendance for each subject using the data obtained from YouTube Analytics.

**ENEN20002 Attendance**

Fig. 4 shows the TLA and WLA for ENEN20002 Semester 1 of 2018. The general trend is that the number of students attending lectures decreases as the semester progresses. In the case of total lecture attendance [TLA, Figs. 4(a and b)], it is estimated that approximately 88% of the class for ENEN20002 watched the first week of lectures and only 30% watched the lectures in Week 12. If the weekly lecture attendance (WLA) is taken into account [Figs. 4(b and c)], the decreasing number of students attending is more distinct, in comparison to TLA. The difference between TLA and WLA [i.e., Figs. 4(a and c) or Figs. 4(b and d)] is equivalent to the number of students attending the lecture outside of the set timetable (i.e., watching Week 3 lectures in Week 4, or catching up on lectures during SWOTVAC). It is estimated that approximately 40% of students watched (attended) the online videos outside of the set timetable, dependent on the week of the semester. Week 5 in Fig. 4(d) corresponds to the week before the Easter holiday period, which may explain the noticeable decrease in attendance.

Furthermore, there are also some noticeable increases in total lecture attendance [i.e., Lectures 4, 6, 7, 16, 19, and 34 in Fig. 4(a)] that are outside of the general trend. This could be because Lectures 4, 6, and 7 covered information required for Assignments 1 and 2 in ENEN20002, whereas Lecture 19 covered content required for Assignment 3. Furthermore, Lecture 16 was covered by a guest lecturer, outside of the primary two lecturers that deliver the content for the subject. Lecture 34 was one of two revision lectures for the subject, which gave an overview of the content and information on the exam, hence the increase in TLA.

If the lecture attendance of Part 2 and Part 3 of each online video lecture is compared to the lecture attendance of Part 1, a decline in student attendance can be observed for almost every lecture. Fig. 5 shows the percentage of students attending (i.e., watching) Part 2 and Part 3 of the lecture series, normalized to the lecture attendance of Part 1 of that same lecture. Some lectures for ENEN20002 throughout the semester were shorter in length than the typical 50 min.

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**Fig. 4.** Lecture attendance for ENEN20002: (a) total attendance as a function of lectures throughout the semester; (b) total attendance as a function of lectures per week; (c) weekly attendance as a function of lectures throughout the semester; and (d) weekly attendance as a function of lectures per week.
Hence, Lectures 1, 34, and 35 had only Part 1 of the video series, and Lecture 32 had only Parts 1 and 2.

**CVEN30008 Attendance**

Fig. 6 shows the lecture attendance for CVEN30008. Similar to ENEN20002, the general trend is that the number of students attending lectures decreases as the semester progresses, with a small increase at the end of the semester. This small increase, which is only prevalent for the TLA [i.e., Fig. 6(b)], is likely due to the lectures at the end of the semester providing content to assignments and end of semester exams. Approximately 73% of the class for CVEN30008 watched the first week of lectures and only 37% watch the lectures in Week 12 [Fig. 6(b)]. The weekly lecture attendance [WLA, Figs. 6(c and d)] shows that the decreasing number of students attending is similar to that in ENEN20002 [Figs. 4(c and d)] and best represented by a logarithmic regression. In fact, the student WLA as a function of the week [Fig. 4(d)] for CVEN30008 follows the same trend as ENEN20002 [Fig. 4(d)]. It is estimated that approximately 27% of students watched the online videos outside of the set timetable, dependent on the week in the semester.

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**Fig. 5.** Student lecture attendance (in percent) of Part 2 and Part 3 of the ENEN20002 lecture series, normalized to Part 1 of the same lecture number.

**Fig. 6.** Lecture attendance for CVEN30008: (a) total attendance as a function of lectures throughout the semester; (b) total attendance as a function of lectures per week; (c) weekly attendance as a function of lectures throughout the semester; and (d) weekly attendance as a function of lectures per week.
Similar to what was observed in ENEN20002, a decline in student attendance can be observed for every lecture when comparing Part 2 and Part 3 to Part 1 of each online video. Fig. 7 shows the percentage of students attending Part 2 and Part 3 of the lecture series, normalized to the lecture attendance of Part 1 of that same lecture.

**Discussions and SES Feedback for Online Lectures**

Using the definition of lecture attendance given in the section “Lecture Attendance” and Eq. (1) it was found that the number of students attending lectures decreases as a function of the semester progressing (i.e., with time) and for both of the subjects investigated. The reduction in total lecture attendance [i.e., Figs. 4(b) and 6(b)] for these online (flipped) classes is similar to the decreasing student attendance trends for traditional, didactic lectures (Von Konisky et al. 2009; Nyamapfene 2010; Van Blerkom 1992). Only an estimated 30% and 37% of students in the flipped streams of ENEN20002 and CVEN30008, respectively, attended the final lectures of the course. This means that these students were potentially unexposed to the content of these lectures. The low number of students attending the lectures at the end of the semester is potentially a sign that the prescribed online videos failed to be engaging or interactive for the majority of the students, which is discussed in more detail subsequently in this section. When comparing the start and finish of the semester, the corresponding drop in attendance for ENEN20002 and CVEN30008 is approximately 60% and 37% of the cohort, respectively. A 30% drop in viewership of online lecture videos was observed in one of the structural design engineering courses that implemented the flipped classroom from Gross and Musselman (2018).

The weekly lecture attendance [i.e., Figs. 4(d) and 6(d)], in comparison to the total lecture attendance, indicates that students had more flexibility with lecture attendance and suggests that a reasonable percentage of students (∼40%) in each flipped class would watch the lecture outside of the assigned week. Although the flexibility in the time to attend the lecture could be seen as beneficial from a student’s point of view, it could be detrimental to the concept of the flipped classroom depending on when the students are actually watching the online video content (and completing the corresponding questionnaires). As explained in the section “YouTube Analytics,” the online (out-of-class) content is required to be completed prior to attending the workshop (in-class) activities. Therefore, if students procrastinate in viewing out-of-class online content, then they may not be prepared to meaningfully participate or learn in workshops. For instance, some students might utilize semester breaks to watch online content after attending relevant workshops. Although it is not indicative that this is the case from the results of this paper (with less than 1% of lecture attendance during the midsemester breaks for both subjects), it is still suggested that more incentives are necessary to encourage students to not only complete the out-of-class activities (i.e., online lectures and questionnaires here) but to do so before attending the corresponding in-class activities.

For both subjects, there was a decrease in lecture attendance rates for Part 2 and Part 3 of the online videos in comparison to Part 1. The decline in lecture attendance, from Part 1 to Part 3, of each lecture, again, is potentially due to the online videos failing to be interactive enough to stimulate the students learning effectively. This is corroborated through some of the SES feedback received by students in this subject at the end of the semester:

- “Online learning is not as effective as I thought. I prefer attending lectures as it is more interactive.” (Student, CVEN30008, Semester 2)
- “The flipped class approach used for this subject was not stimulating.” (Student, CVEN30008, Semester 2)
- “The online lectures were pretty boring and the lecture did not do anything to stimulate learning.” (Student, CVEN30008, Semester 2)
- “I believe that a live lecture should be conducted completely differently to a recorded video lecture. The style of lecturing and media used be different. Simply recording last semester lectures was not acceptable.” (Student, ENEN20002, Semester 1)

Although the SES did include some negative feedback regarding the use of online lectures, such as in the foregoing, there were also a large number of positive responses regarding the use of online lectures for these subjects:

- “Online lectures, although a bit of a pain, allow me to watch them in my own time.” (Student, CVEN30008, Semester 2)
- “Online lectures is also convenient and considerable.” (Student, CVEN30008, Semester 2)
- “I think the lectures being online were a good idea.” (Student, CVEN30008, Semester 2)
- “Online lecture were very good.” (Student, CVEN30008, Semester 2)
- “This subject provides online lectures which allow students to study at their own time.” (Student, ENEN20002, Semester 1)
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- “This subject provides online lectures which allow students to study at their own time.” (Student, ENEN20002, Semester 1)
- “Online lectures are good and effective.” (Student, ENEN20002, Semester 1)
Thus, if done correctly (i.e., interactively and engaging), the online video lectures as a substitute for the traditional, in-person, and didactic lecture could be an effective way for students to learn content. The authors concede that using the lecture capture series from the previous semester, although providing the same content, might not be the best way to present the content in an interactive and stimulating environment.

### Quiz Results

As stated in the section “Questionnaires,” students were provided with a questionnaire after each part of the online lecture video. The questionnaires were compulsory, such that each week’s content would only be discoverable to the student in the LMS if an attempt at the quiz had been made. A more thorough description of the setup of the quiz is given in section “Questionnaires.”

The results of the quizzes are provided in the sections “ENEN2002 Quiz Results” and “CVEN30008 Quiz Results,” and the section “Quiz Results and Final Grades” provides an overall discussion of these results and any relevant SES feedback from the students.

#### ENEN2002 Quiz Results

Fig. 8(a) shows the average score (AS) of the quizzes for ENEN2002 as a function of the number of quizzes progressing throughout the semester, whereas Fig. 8(b) presents the percentage of completed attempts (CA) by students. As the semester progresses (i.e., from Quiz Number 1–95 for ENEN2002), the average score decreases. This decrease may have resulted from some students making a careless or hasty selection of solutions to unlock sequential material. The results (or grades) from the questionnaires ultimately had no bearing on the student’s final grades for the subject. This observation is further corroborated as shown in Fig. 8(b), in which a distinct pattern is evident; the quiz for Part 3 of the final lecture of each week has a noticeable decrease in the number of completed attempts. As this was the last quiz in the series for that week, it did not release any new content or information for the student (Fig. 2), and thus some students felt reluctant to even attempt this quiz.

Interestingly, the total overall quiz score (in percent) increases as a function of the final grades of the students in ENEN2002, as shown in Fig. 9. It should be emphasized again that the quiz, and the resulting marks from the quiz, did not form part of the overall assessment. Instead, the quiz was used as a tool for student engagement, lecture reflection, and revision, and also to change the activity in restoring some performance of student effective learning (see the section “YouTube Analytics”). However, there is a clear correlation between students who did well in the quiz and in ENEN2002, as indicated by their final grade. The final grades for both ENEN2002 and CVEN30008 are primarily computed from the results of the students’ performance of several assignments throughout the semester and final exam. The assignments and exams from both subjects are aimed at assessing content that addresses several intended learning outcomes (ILO). The questionnaires also aimed to address the same ILO by assessing the same content taught in the lecture series.

Table 2 gives the mean and standard deviation of the overall quiz scores as a function of the final grades in different bin ranges for ENEN2002. For example, the students in ENEN2002 who received a final grade greater than (or equal to) 80 but less than 90 had a mean (μ) overall quiz score of 75.3% with a standard deviation (σ) of 13.8%. Note that the average overall μ quiz score increases with an increasing bin range of final grade for both subjects. Conversely, the students who received a grade lower than 50 only achieved an overall μ quiz score of 37.0% with a σ of 26.1%.

![Fig. 8. Quiz results for ENEN2002 over the semester: (a) AS score (in percent); and (b) CA by enrolled students as a function of the quiz number (QN).](image-url)

![Fig. 9. Correlation between final grades and mean overall quiz scores in ENEN2002, in which a line-of-best-fit is given for the mean overall quiz score (QS) as a function of the final grade bin (g_f).](image-url)
The AS of students in CVEN30008 for each of the quizzes is shown in Fig. 10(a), whereas Fig. 10(b) presents the percentage of CA by students. Similar to ENEN20002, as the semester progresses the average student score for the quizzes decreases. Unlike ENEN20002, a quiz was not provided corresponding to Part 3 of each lecture series. In turn, the completed attempts by students for the quizzes in CVEN30008 [Fig. 10(b)] shows a very different trend in comparison to ENEN20002 [in Fig. 8(b)], which is well correlated to a logarithmic function.

**CVEN30008 Quiz Results**

The AS of students in CVEN30008 for each of the quizzes is shown in Fig. 10(a), whereas Fig. 10(b) presents the percentage of CA by students. Similar to ENEN20002, as the semester progresses the average student score for the quizzes decreases. Unlike ENEN20002, a quiz was not provided corresponding to Part 3 of each lecture series. In turn, the completed attempts by students for the quizzes in CVEN30008 [Fig. 10(b)] shows a very different trend in comparison to ENEN20002 [in Fig. 8(b)], which is well correlated to a logarithmic function.

**Quiz Results and Final Grades**

Similar to the observations for ENEN20002, the total overall quiz score (in percent) increases as a function of the final grades of the students in CVEN30008, as shown in Fig. 11. Table 3 gives the mean and standard deviation of the overall quiz scores as a function of the student final grades in different bin ranges for CVEN30008.

For example, the students in CVEN30008 who received a final grade greater than (or equal to) 80 but less than 90 had a mean (μ) overall quiz score of 76.6% with a standard deviation (σ) of 26.2%. Conversely, the students who received a grade greater than (or equal to) 50 but less than 60 only achieved an overall μ score of 31.1% on the quiz with a σ of 36.0%. As was observed with ENEN20002 in “ENEN20002 Quiz Results,” the average overall μ quiz score in CVEN30008 increases with an increasing bin range of final grade for both subjects. For CVEN30008 (Table 3), the σ was also found to decrease with the increasing bin range of the final grade.

**Discussions and SES Feedback for the Compulsory Quiz**

Overall, the quiz received overwhelming praise in the SES feedback for both subjects:

- “The online lectures with quizzes, followed up with a review lecture [i.e. denoted as the end of week tutorial], worked well for me. The quizzes kept me focused and the shorter releases of lecture segments felt easier to handle.” (Student, ENEN20002, Semester 1, 2018)

**Table 3. Final grades and correlation with quiz results for flipped CVEN30008**

<table>
<thead>
<tr>
<th>Data description</th>
<th>Final grades</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≥50−&lt;60</td>
</tr>
<tr>
<td>No. of students (%)</td>
<td>3.7</td>
</tr>
<tr>
<td>No. of students (%)</td>
<td>31.1</td>
</tr>
<tr>
<td>Mean quiz score (μ) (%)</td>
<td>36.0</td>
</tr>
<tr>
<td>Standard deviation quiz score (σ) (%)</td>
<td>T3:4</td>
</tr>
</tbody>
</table>

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“I thought the online lectures worked well because the concept of having quizzes online in between lectures really reinforced my learning.” (Student, CVEN30008, Semester 2, 2018)

“[The] best part was the online lectures [and] how we had to do quiz’s for each part. That was quite effective for me in learning the content.” (Student, CVEN30008, Semester 2, 2018)

“…quiz after watching on-line lecture. This helped me to digest contents more easily.” (Student, CVEN30008, Semester 2).

Students who achieved high overall scores from the quiz generally received achieved high grades in CVEN30008 at the end of the semester. Conversely, the students who received low overall quiz scores were more likely to receive a poor final grade for the subject. Moreover, low overall quiz scores often correlated with students who did not complete many of the quizzes, ultimately meaning that much of the learning content (i.e., online lecture videos) of the subject may not have been available to them (Fig. 2).

This would offer an explanation for the low overall quiz scores typically corresponding to low final grades. Students had unlimited attempts for each of the quizzes; if a student did poorly in the quiz, feedback was provided with the correct answer and the student could attempt the quiz again. In the study by Hotle and Garrow (2016), a correlation was shown to exist between students who were successful in quizzes and higher GPAs. However, Hotle and Garrow (2016) note that this correlation could simply be emphasizing that students who had already been successful in the traditional stream were likely to be successful in the flipped stream, as these were students who also “started homework assignments earlier, began studying quizzes earlier, and attended office hours.”

Instead of releasing content after the student has only attempted the quiz, it might have been a better approach to release the content only after a certain score was reached in the quiz that can be attempted multiple times (e.g., 80% or thereabouts). The number of attempts made and the resulting scores can also help identify at-risk students that subject coordinates can follow up with early on in the semester.

For ENEN20002, the quiz corresponding to Part 3 of the final lecture for that week was not attempted by some students. This was likely due to a lack of incentive for students to complete this quiz as completing it would not release any new content. Thus, more incentives may be necessary to get students to complete all of the quizzes and want to do well. For example, it might be necessary to make the resulting scores from the quiz contribute to the overall assessment of the subject; this was also suggested by a student in the SES feedback:

“…the quizzes should also be counted as an assessment with a time limit to ensure us keeping up to date.” (Student, ENEN20002, Semester 1, 2018)

Alternatively, the quiz corresponding to Part 3 of the online lecture could release the content for the following week (i.e., the quiz for Week 1, Lecture 3, Part 3, once attempted, would release Week 2, Lecture 4, Part 1).

### Survey Forms

As discussed in the section “Surveys,” students were asked to complete a survey at the beginning of the flipped semesters of ENEN20002 and CVEN30008. The survey questions were adapted from the research conducted by Butt (2014).

### Survey Results from ENEN20002

A total of 97 students (73%) answered the survey questions for ENEN20002 (Semester 1, 2018) and the results for Question 1 and Question 2 are given in Tables 4 and 5, respectively. A numerical value was used to rank the activities: 3 corresponded to least, 2 corresponded to some, and 1 corresponded to a lot. In this way, a lower rank corresponds to a higher preference for that activity, similarly used in Butt (2014).

The results given in Table 4 indicate that on average students in ENEN20002 perceive to learn most from performing an activity. In fact, these results show the same average ranking of perceived learning activities in comparison to the 62 students enrolled in actuarial studies from Butt (2014), who were surveyed with the same questions.

Although the study from Butt (2014) showed the surveyed actuarial students had a clear preference against group study, as given in Table 5, the surveyed engineering students enrolled in ENEN20002 showed no clear preference for lectures, tutorials, individual study, or group study. However, on average there is a slight preference for tutorials and a slight preference against group study activities.

Butt (2014) examined the responses from only the students who did not use English as a primary language of communication outside of the university, in which lectures were preferred over individual study. For this paper, the survey asked students whether or not they were a local student. Given that the top five nationalities (outside of Australia) enrolled in higher education in the Australian education system are China, India, Nepal, Vietnam, and Malaysia (AIE 2019), the assumption that nonlocal students do not use English as a primary language seems reasonable. If the responses from local students in ENEN20002 are only examined, performing an activity and tutorials stand out as clear preferences for Questions 1 and 2 of the survey, respectively, with average scores of 1.13 and 1.28. In contrast, when nonlocal students are examined, no clear preferences are present, with lectures being slightly preferred for Question 1, with an average score of 1.51, and a slight preference against group study for Question 2, with an average score of 1.75.

### Survey Results from CVEN30008

A total of 123 students (30%) answered the survey questions for CVEN30008 (Semester 1, 2018). The low percentage of students surveyed is as a result of the number of workshops the author could attend to administer the surveys within the first week, rather than the number of students deciding to opt out. Tables 6 and 7 give the results of these completed surveys for Question 1 and Question 2, respectively.

The results given in Table 6 indicate similar observations to those in the previous section for the engineering students in ENEN20002; on average, the surveyed students enrolled in CVEN30008 perceive to learn most from performing an activity.
For the engineering students in CVEN30008, a clear preference against group study can be observed as given in Table 7. The actuarial students in the research by Butt (2014) also had a clear preference against group study. Furthermore, a preference for tutorials can be observed as given in Table 7, which was the same for the students in ENEN20002 (see Section “Survey Results from ENEN20002”).

If the responses from local students in CVEN30008 are only examined, performing an activity and tutorials stand out as clear preferences for Questions 1 and 2 of the survey with average scores of 1.29 and 1.26, respectively. These results for local students were the same as the perceptions given in the previous section for ENEN20002. In contrast, when nonlocal students are examined, no clear preferences are present, with a slight preference against group study for Question 2, similar to the nonlocal students in ENEN20002 (in the section “Survey Results from ENEN20002”), with an average score of 1.79.

Discussion of Survey Results

The results of the surveys conducted by some students enrolled in two different engineering subjects investigated indicated that they perceived to learn most from performing an activity, instead of listening to someone talk, and in tutorials rather than traditional lectures. Although more research is necessary to conclusive say that this is the case, the results herein support the supposition that a flipped classroom approach for subjects at the university level could be a beneficial method for improving the effectiveness of student learning. These results also help substantiate those in Butt (2014), in which the results from the survey indicated that a “flipped classroom approach could be perceived as a positive approach to the university classroom due to its combination of activity and demonstration.” However, research from Ling and Gan (2020) indicated that students’ perceptions of teaching modes at the start of the semester are not a good gauge of whether another teaching mode would be effective. Thus, it is recommended that future surveys on this topic gauge students’ perceptions at both the start and end of the semester.

Conclusions and Recommendations

This paper focused on the effectiveness of flipping the classroom for two university engineering subjects. Most of the previous research found included studies that typically relied on the perceptions of students to dictate whether the subject had been successfully flipped. In this paper, the authors used a range of different data sources to determine effectiveness.

Although there was no drastic change in final grade distributions when comparing the students enrolled in the flipped stream with the traditional stream (Fig. 12), some evidence from this paper suggests that a flipped classroom would be a more preferred method of learning for these students. For example, the survey results of over 200 engineering students perceived they learn the most from in-class activities during workshops (or tutorials), rather than listening to someone and in lectures. If implemented correctly, these results indicate that the flipped classroom approach could be perceived positively by students. More importantly, it could improve effectiveness in learning content.

The following is a summary of some of the results using other sources of information for determining the effectiveness of the flipped classroom implemented for these two subjects:

1. Using the lecture capture series from previous semesters did not provide an engaging or stimulating experience to students for the online video series in the flipped classes. As a result, the total lecture attendance numbers (i.e., watching online lecture video) decreased as the semester progressed, which was at a comparable rate to trends for the traditional in-person
lectures, and (2) lecture attendance also decreased from Part 1 to Part 3 of the same online lecture video.

2. Comparing the weekly lecture attendance to total lecture attendance showed that students had more flexibility to allocate their time better and watch the lectures at their own pace.

3. There was a positive trend between questionnaire scores and final grades for both subjects. Although this suggests some correlation between the students who did well on the quiz generally doing well in the subject, the standard deviations for the quiz scores within each bin make it difficult to say this conclusively.

4. The average questionnaire scores decreased as the semester progressed.

Due to these findings, some recommendations are given, which can be used by teaching practitioners at the university level when attempting to flip their own subjects. Although the results from this paper came from students enrolled in two engineering subjects, it is expected that these recommendations can be used for a range of different faculties, disciplines, and subjects:

1. The online lecture videos should be carefully created to ensure student engagement and continued stimulation (i.e., the lecture capture from previous semesters, as was used for the subjects focused on for this paper, failed to do this). Videos should be prepared specifically for the flipped version of the subject, whether that is using a simple webcam capture program or using more sophisticated methods (i.e., green screen and high-quality cameras). The method of filming and providing the video online will ultimately rely on the digital technology proficiency of the teaching practitioner, the access to training provided by the university, and the amount of time to prepare the subject.

2. Some form of incentive might be required to persuade students to watch (or attend) the online, out-of-class video lectures. For example, Gross and Musselman (2018) achieved a near-constant attendance rate of approximately 90% for an engineering course by applying a small amount (4%) of the total grade to viewership. In contrast, Gross and Musselman (2018) observed a drop in attendance, from 90% at the start of the semester to 60% as the semester progressed, for another engineering course that did not attach a grade to viewership.

3. The length of the video lectures should be no more than 15 min (Gross and Musselman 2018; Li and Daheer 2017; Wilson and Korn 2007).

4. A change in activity, such as the questionnaires, should be implemented after students have watched 10–15 min of the online lecture. The authors suggest the questionnaire as the change in activity, which was successfully used in the two subjects focused on for this paper. The questionnaire also allows students to reflect and review the content and could have a positive impact on their final grades.

5. The change in activity (i.e., questionnaire) should be used to release content, which was used successfully for these two subjects.

6. If the questionnaires are used, they should form part of the overall assessment to motivate students to complete the quiz, with multiple attempts being allowed.

The results from this paper and the recommendations given will be used to further improve the implementation of the flipped classroom method for subjects in the Department of Infrastructure Engineering at the University of Melbourne. Further research is required to understand the perceptions of students’ effectiveness in learning and the best methods of practice and application of the flipped classroom model.

Appendix I. Plain Language Statement

Project:

The Flipped Classroom: An Investigation Comparing the Traditional Teaching Methods to Online Student Learning at the University Level

Dr. Ryan Hoult (Primary Researcher)
Dr. Murray Peel (Secondary Researcher)
Tel: +xx xxxxxxx Email: ryan.hoult@unimelb.edu.au

Introduction

Thank you for your interest in participating in this research project. The following few pages will provide you with further information about the project, so that you can decide if you would like to take part in this research.

Please take the time to read this information carefully. You may ask questions about anything you don’t understand or want to know more about.

Your participation is voluntary. If you don’t wish to take part, you don’t have to. If you begin participating, you can also stop at any time.

What is this research about?

This project activity is mainly aimed at assessing the effectiveness of the “flipped classroom,” which is a teaching method that involves more online material and content. For example, instead of attending lectures, students enrolled in a particular subject might watch lectures online.

The detailed objectives of this activity are listed below

• To assess the participating students’ abilities to learn the material using the two different methods of teaching by comparing assessment results.
• To assess the feedback provided by the students who participate.
• To evaluate the participating students’ perceptions on effective learning and if the ‘flipped classroom’ method is preferred.

Altogether, students in two subjects (ENEN20002 and CVEN30008) can be participants in this study. Some students enrolled in these subjects may be subjected to the learning material via the traditional means (e.g., attending lectures). In other semesters, the ‘flipped classroom’ approach may be implemented for a subject, which includes online content (including lectures).

What will I be asked to do?

A short survey will be asked to the participants (students) in each class before and at the end of each semester. The survey shouldn’t take more than a couple of minutes to complete and is in a similar format to that used in other research, such as that in Butt (2014).

The responses (written feedback) provided by the survey from the participants may also be used in this research. Participants are encouraged to put their opinion/view on these given issues during the survey.

Furthermore, the grades (marks) of the students may also be used to assess the effectiveness of the teaching methods using some statistical analysis. It should be emphasised that this research will protect your confidentiality and maintain anonymity while collecting and using any information.

After this information/data has been collected and used in the research, the data will be destroyed. It should be further emphasised that this data will not collect any personal information (such as names, student ID’s, etc).

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Furthermore, the grades (marks) of the students may also be used to assess the effectiveness of the teaching methods using some statistical analysis. It should be emphasised that this research will protect your confidentiality and maintain anonymity while collecting and using any information.

After this information/data has been collected and used in the research, the data will be destroyed. It should be further emphasised that this data will not collect any personal information (such as names, student ID’s, etc).
What are the possible benefits?
There are many changes currently facing Universities and the methods in which material and information is taught. The traditional methods of teaching at University, which typically involve several lectures per week that students are encouraged to attend and a 1-h tutorial, are under scrutiny. Given that the internet has allowed information to be readily available to all students, the ‘flipped classroom’ may provide a more effective way of teaching. Moreover, providing more online content to the students may provide to be a more convenient way of learning to the students.

The methods that will be employed by the University in the near future could affect the way you are intended to learn the material. By participating in this research, you can have your say as to whether you prefer attending lectures or prefer online content (lecture, quizzes, etc).

What are the possible risks?
There are no foreseeable major risks arising from participation in this survey.

Do I have to take part?
No. Participation is completely voluntary. You can withdraw at any time. It is important to note that although there could be dependent relationships involved, decision to participate or not to participate in the research should not affect student assessment in any way.

Will I hear about the results of this project?
Yes, the results of this research are intended to be published either by conference paper or journal paper.

What will happen to information about me?
No personal identifying information of the participants will be collected. Furthermore, no individual will be referred to in the analysis or published results.

Who is funding the research?
The University of Melbourne is entirely funding this research.

Who has access to the data?
The data will be electronically recorded through the Learning Management System. Access to this is restricted to the primary researchers (Dr. Ryan Hoult and Dr. Murray Peel). The obtained data and feedback from the surveys will be stored on password protected files on University computers with access restricted to Dr. Ryan Hoult for 7 years from the date of publications arising from the data, and will then be destroyed.

Where can I get further information?
If you would like more information about the project, please contact the researcher by phone or email; Dr. Ryan Hoult, +xx xxxxxxxxx, ryan.hoult@unimelb.edu.au

Who can I contact if I have any concerns about the project?
This research project has been approved by the Human Research Ethics Committee of The University of Melbourne. If you have any concerns or complaints about the conduct of this research project, which you do not wish to discuss with the research team, you should contact the Manager, Human Research Ethics, Research Ethics and Integrity, University of Melbourne, VIC 3010. Tel: +61 3 8344 2073 or Email: HumanEthics-complaints@unimelb.edu.au. All complaints will be treated confidentially. In any correspondence please provide the name of the research team or the name or ethics ID number of the research project.

Ethics ID Number: 1750529.1 Plain Language Statement

Appendix II. Survey

Project:
The Flipped Classroom: An Investigation Comparing the Traditional Teaching Methods to Online Student Learning at the University Level

Dr. Ryan Hoult (Primary Researcher)
Dr. Murray Peel (Secondary Researcher)

Tel: +xx xxxxxxxxx Email: ryan.hoult@unimelb.edu.au
Name: Student Number:
Gender:
Subject:
Local Student? [Y/N] . . . . . .

Question 1. Rank the following activities in order of which you believe you learn the most from:

<table>
<thead>
<tr>
<th>Activity</th>
<th>A lot</th>
<th>Some</th>
<th>Least</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading, Text, Graphs etc</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Listening to someone talk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performing an activity</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Question 2. Rank the following University activities in order of which you believe you learn the most from:

<table>
<thead>
<tr>
<th>Activity</th>
<th>A lot</th>
<th>Some</th>
<th>Least</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lectures</td>
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<td>Tutorials</td>
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<tr>
<td>Individual Study</td>
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<td></td>
</tr>
<tr>
<td>Group Study</td>
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</table>

Data Availability Statement

Data generated by the authors or analyzed for this paper are available from the publicly accessible platform Zenodo, https://www.doi.org/10.5281/zenodo.3564900.

The data includes: (1) YouTube analytics, (2) survey results, and (3) MATLAB files (for reproducing graphs and figures) and is organized as described in the report Data_organization_Flipped_2020.pdf. This allows for transparency of the data and files that were used to compile the results in this paper and to facilitate conducting replicability studies. This also allows for greater opportunities for sharing and reusing the research data produced from this paper, which may help future studies that focus on similar topics.

References


