ADAPTING TO THE EMERGENCE OF GENERATION Z IN TERTIARY EDUCATION: APPLICATION OF BLENDED LEARNING INITIATIVES IN TRANSPORT ENGINEERING

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Abstract

Background: Civil Engineering, specifically Transport Engineering, is a continually evolving profession. Recent developments in technology has resulted in more automated and visual problem solving techniques, involving the use of computer programs and simulation, as practitioners and researchers move away from traditional "pen and paper" approaches. Accordingly, teaching undergraduate university students the basic principles of transport planning, traffic engineering and highway design effectively is fundamental to the sustainability of the profession. It is also a challenging and dynamic task for educators as enhanced accessibility to technology has changed the way students understand and learn the material being delivered at tertiary education institutions.

Purpose: This paper presents the development of, and feedback from, the implementation of a series of "Blended Learning" initiatives (interactive polling exercises, online quizzes, supplementary learning videos, authentic real-world design project), within an introductory large class-size transport planning and geometric design subject.

Method: The process of developing the blended learning initiatives were documented to clearly highlight the benefits and challenges in the transformation process. In addition, qualitative student feedback and student performance between 2016 and 2018 were reviewed to understand the impacts of the transformation.

Results and Conclusion: The initiatives were well received, with students valuing self-paced learning and the exposure to real-world design exercises. From an educator's perspective, blending made it feasible to deliver complex content whilst offering tailored learning opportunities across the cohort. Though further comprehensive experiments and statistically oriented research is necessary, this case study adds to a growing body of literature that indicate

the potential value of blended learning initiatives, especially in the context of large class size University subjects.

Keywords: Blended Learning, Interactive Lecturing, Project-Based Engineering Assessments

Introduction

Generation Z, also known as post-millennials, are people who have birth years ranging from the mid-1990s to the mid-2000s. The most significant difference between Generation Z and previous generations is the childhood exposure to the internet and the desire for, and dependency on, technology. Brains develop based on environmental influences. Literature suggests that technology has wired Generation Z to be attuned to sophisticated complex visual imagery, thus indicating that visual forms of learning may be more effective than the traditional lecture or discussion formats (Srinivasan, 2016, Turner, 2015, Cilliers, 2017). Furthermore, there is a shift in career perspectives. Previous generations appreciated stable jobs with good income whereas post-millennials are looking for continual advancement in their profession and prefer to work based on personal interests (Srinivasan, 2016, Swanzen, 2018). The rapid change in technology has also transformed most industries with current employees requiring at least basic computer literacy while new staff are expected to be proficient and innovative with technology (Turner, 2015, Shatto and Erwin, 2017). The first batch of Generation Z (those born between 1995 and 2002) are currently entering or completing their studies at tertiary institutions around the world. Therefore, it is important for educators to acknowledge the generational shift, and tailor the delivery of learning material to meet the expectations of the students and the needs of industry. In addition to the generational transition, enrolments at most tertiary institutions are increasing dramatically which will ultimately increase class sizes. This limits the effectiveness of traditional teaching approaches (Prosser and Trigwell, 2014, Cuseo, 2007).

Blended learning approaches have become prevalent to provide scalable education that satisfies the expectations of students. The definition of "blended learning" is not universal. In the context of this paper, a blended learning approach is defined as "*a flexible learning and teaching method, which attempts to integrate the best face-to-face and online course delivery modes to achieve the desired learning objectives for students*" (Rahman, 2017). Thus, these teaching mechanisms aim to take advantage of technology to offer a flexible self-paced learning environment that utilizes face to face time with students to conduct interactive skill development sessions. Chicca and Shellenbarger (2018) discuss the generational shift in education delivery in the context of nursing. The study clearly establishes a need for more innovative approaches (blended, virtual, interactive gaming approaches) in combination with experiential learning. Ding et al. (2017) conducted a comprehensive study concerning game-based learning concepts of Finance, promoting the need for innovation in education with an evolving society. Similar findings are also present in other gamification in education studies (Manzano-León et al., 2021), However, there are limitations and barriers to blended learning techniques, especially those that involve increased interactions with digital and virtual media. Research has indicated that increased screen time, and the lack of real world interactions, have been perceived as a challenge for students (Pikhart, 2019), while digital literacy is important for blended learning to be effective (Tang and Chaw, 2016). It could be argued that these challenges are diminishing, especially in the context of the more digitally literate and virtually aware cohorts of Generation Z.

The COVID-19 pandemic has also accelerated the transition towards a blended environment. The unprecedented circumstances forced online learning which, in some contexts, provided greater flexibility for students and enhanced performance and outcomes (Singh, 2021). Furthermore, Megahed and Hassan (2021) suggests that, in the near future, there will be an expectation by the community that supplementary online resources or distance learning options will be automatically available to students. However, student surveys conducted by Mali and Lim (2021) clearly demonstrate that “online only” learning is far less superior than face to face suggesting even more heightened importance of blended strategies. Students attend class face to face for interactive sessions whilst absorbing theoretical and conceptual topics online. In addition, Science and Engineering tertiary degrees are at the forefront of developing technology. Students undertaking these degrees are generally skilled with, or at least extremely motivated to learn about, the latest technology. It is particularly important for subjects within these degrees to deliver material in a format that is suitable for Generation Z, which can potentially be achieved through blended learning initiatives. These initiatives can offer students’ opportunities to enhance skills in computer programming and exposure to industry used software.

This paper presents a case study of a series of blended learning teaching initiatives applied during the autumn semester of 2017, to an introductory compulsory undergraduate transport subject, CVEN2401: Sustainable Transport and Highway Engineering (CVEN2401) at the University of New South Wales (UNSW) in Sydney, Australia. CVEN2401 was suitable for these initiatives because it generally demands enrolments in excess of 350 students, introduces fundamental knowledge required by students in future years, and also covers complex modelling and three-dimensional designs which require visualizations. Student feedback and performance across assessment tasks were compared across the 2016, 2017 and 2018 cohorts who completed CVEN2401. The purpose of the paper is to document the development and implementation of blended learning initiatives tailored to the delivery of a core Transport Engineering subject in an Undergraduate Civil Engineering Degree. This subject can be compared with most introductory subjects within the discipline, thus the techniques and lessons learned can be leveraged in other institutions. Though the paper does not provide statistical evidence for the advantages or disadvantages of blended learning applications, the intent is to share the experiences of the case study application. The research provides additional perspectives related to blended learning implementations in a large class size setting, within a tertiary education environment.

Background

The popularity and necessity of alternative teaching methodologies, in particular blended learning activities, have been evident since the turn of the century (Garrison and Kanuka, 2004, Drysdale et al., 2013). Boelens et al. (2017) provides a recent review of blended learning applications across all higher education institutions and highlight the four key challenges in ‘blending’ a course: incorporating flexibility, stimulating interaction, facilitating students’ learning processes and fostering an effective learning environment. The review indicates that there is a separation of online content and traditional lecture material without a cohesive integration of both resources. For example, entire topics may be presented online with no face-to-face discussion regarding those topics, limiting the effectiveness of blending (Rasheed et al., 2020). This aspect, along with others from the review, was closely considered when developing the initiatives within this study.

The effectiveness of teaching strategies involves aligning learning outcomes with the personal goals of the students which are dependent on the discipline. Kirn and Benson (2018) conducted a series of interviews with students and completed an interpretative phenomenological analysis (IPA) to understand the motivation for studying engineering. The study revealed that participants perceived engineering as being primarily a problem-solving process and the level of engagement and interest of the subject matter was dependent on how the content would assist in problem solving. This notion is also reflected in an earlier study by Ellis et al. (2008) which highlighted the importance of developing and delivering “deep” material, rather than “surface level” material, to engineering students in order to ensure cohesive comprehension. In other words, it is important to convey cause and effect as well as application. Building on from the study completed by Boelens et al. (2017), Lo and Hew (2019) present a review of "flipped learning" applications within engineering education. Flipped learning strategies involve students learning fundamentals away from class and then participating in active application focused learning during class. These are a subset of blended approaches; however, the findings are relevant to the study presented in this paper as a number of initiatives developed could be interpreted as a flipped approach. Lo and Hew (2019) conducted a meta-analysis of 29 flipped interventions which presented statistically significant results, indicating superior student learning and performance in a flipped environment, further justifying the initiatives developed in this study.

Applications of blended learning are numerous in the Engineering domain. Overall, implementations resulted in positive outcomes (Alkhatib, 2018, Alonso et al., 2005, Winterstein et al., 2012). Rahman (2017) introduced online recorded material, quizzes and a discussion board that enhanced student outcomes in an introductory Fluid Mechanics class (student satisfaction increased by 18% over a 4 year period). Harris and Park (2016) focused on creating adaptive and hands on in-class assessment tasks within a core theoretical subject concerning mechanical and thermal energy conversion processes. There have been a number of studies that have also investigated the use of polling and online student response systems (Dabbour, 2016, Dabbour, 2017, Lyubartseva, 2013, Salemi, 2009). A particularly relevant study by Dabbour (2017), which applied the technique in a transport engineering subject, presented enhanced student performance as well as attendance. These positive studies also highlighted the importance of using appropriate classroom spaces that facilitate interaction and ensuring enough time is scheduled to complete adaptive activities. Such findings shaped the development of the initiatives for CVEN2401. In addition, Francis and Shannon (2013) explored the blending of architectural design and construction management courses and revealed the potential for inequity when students can not engage across the variety of teaching methods that are implemented. Stricker et al. (2011) further adds that the benefits of blending are only achieved in an environment where all students can access and utilize the available resources. This is compounded in a large class-size setting and is explored further in the research presented in this paper.

Focusing on Transport Engineering, the core topic area of the CVEN 2401 case study, Hurwitz et al. (2015) presents a comprehensive review of instructional practices and innovations within the discipline (Hurwitz et al., 2015). 46 papers were reviewed as part of the study and practices were categorized in terms of simulation, visualization, problem-based learning and active-learning techniques. Possibly the most disseminated teaching innovation in Transport Engineering, is a suite of simulation-based exercises, collectively named "STREET: Simulating Transportation for Realistic Engineering Education and Training", which has been developed by Professor David Levinson and the researchers at the University of Minnesota (Chen and Levinson, 2006, Liao and Levinson, 2012, Liao et al., 2009, Zhu et al., 2010). The tools include an agent-based demand and assignment model (ADAM) (Zhu et al., 2010), an online application of signalized intersection simulation (Zhu et al., 2010), an online application for road design (ROAD) (Liao and Levinson, 2012) and a simulator of network growth (SONG) (Chen and Levinson, 2006). Students learn through using these tools to complete assignments and exercises which are supplemented by technical knowledge gained from lectures, which inverts traditional "chalk and talk" methods focused on theoretical understanding of material. The STREET modules received resoundingly positive student feedback and improved student knowledge retention, serving as an example for the blended learning initiatives developed for CVEN2401.

Extensive work outside of the University of Minnesota has also been completed. Sun et al. (1999) developed a program where students at the University of Oklahoma developed a virtual city, "Sooner City", as a means to learn the core principles of traffic engineering and road design. The visualization and self-paced learning environment improved problem identification but were only mildly successful in achieving improved understanding of the underlying principles. Academics at the University of Idaho developed a series of activities involving traffic simulations and animations to teach traffic signal timing (Brown et al., 2013). Students improved their understanding of cycle time, delay and passage time as a result of these initiatives. Experience based learning and project-based course work has also been used to teach pavement design and construction (Fini and Mellat-Parast, 2012, López-Querol et al., 2014) and highway design and construction (Melin et al., 2010, Nicholas et al., 2003), all presenting valuable learning experiences for students. The primary challenge of implementing project-based activities is to achieve scalability, which could potentially be achieved through combining online resources. It is clear that there are numerous cases of digital uplift and subject enhancement around the world, and these have been used as a foundation to develop the initiatives for CVEN2401. The novelty of blending in CVEN2401 appears through the implementation of a combination of initiatives, through visualization, interaction and project based learning. To understand the initiatives that have been developed, it is important to know the structure and purpose of CVEN2401, which is discussed in the following sub-section.

CVEN2401: Sustainable Transport and Highway Engineering

CVEN2401 is a core subject of the Civil Engineering curriculum offered to second year Undergraduate students by the School of Civil and Environmental Engineering at UNSW. Between 2015 and 2018, the subject has had in excess of 350 enrolments each semester (gender split of approximately 75% male to 25% female), classifying it as a large class teaching environment. Students undertake CVEN2401, after completing fundamental subjects in mathematics, physics, computing and chemistry. The subject serves as an introduction to Transport Engineering, similar to subjects like "Mechanics" which introduces students to

Structural Engineering. When undertaking CVEN2401, students have five contact hours each week, which include three hours of lectures and a two hour workshop which is guided by experienced demonstrators who have either taken the subject before or are PhD candidates studying Transport Engineering. The subject material focuses on various fundamental aspects of transport planning, network design, and civil infrastructure design. The subject is taught in two streams (six weeks each). The first six weeks of the subject is jointly taught to both Civil and Environmental Engineering students (the material is taught to Environmental Engineering students undertaking CVEN2402, the companion subject to CVEN2401 taught to Civil Engineering students) concerning the topic of transport planning and modelling. Introductions to the four-step planning process: trip generation, trip distribution, mode choice and trip assignment, traffic flow theory and queuing theory are presented to the students to develop fundamental field specific knowledge. This culminates in a week concerning applications of theory and principles learnt during the first five weeks. The second stream of CVEN2401, geometric design and road construction, is exclusively taught to Civil Engineering students. Basic kinematics and physics principles pivotal to the design of roads, are introduced in the first lesson which is followed by a series of lectures showcasing the road design process. Route selection through the appraisal of topography and geographic environment, vertical alignment, horizontal alignment and earthworks considerations are presented in conjunction with the relevant road design guidelines for Australia (Austroads Guide to Road Design).

The major challenges faced in delivering CVEN2401 are the large class size as well as the broad range of topics covered in the subject. These complexities are common in many introductory Engineering subjects; however, this subject presents material which draws upon and develops knowledge in the domains of economics, game theory, statistics and optimization, all unfamiliar to second year Civil Engineering students. Specifically, mathematical concepts underlying transport modelling, such as equilibrium in traffic assignment and gravity models are abstract for a majority of students. Further difficulty is faced, when delivering concepts involving the translation of three-dimensional road designs into two-dimensional drawings, requiring students to develop an intuition and understanding from different planes and perspectives. As the literature has shown, to date, these complexities and challenges have been mitigated through the use of technology and a shift towards a more ‘Blended Learning Environment’, which provide the impetus for change within the subject.

Development of Blended Learning Initiatives

A series of blended learning initiatives were developed using funding support provided by the School of Civil and Environmental Engineering at UNSW. **Table 1** presents a summary of the four initiatives first implemented in CVEN2401 during Semester 1 (autumn) of 2017 (March to June, 2017), highlighting the objectives and technology used.

Interactive Lectures

Large class environments reduce the interaction between the lecturer and students when delivering a subject using a traditional teaching format. Students are reluctant to ask questions or halt proceedings during the lecture while the lecturer is unable to gauge student understanding of the material. Since the 1960s, “Student Response Systems” (SRS), and other in-class-student-polling technology, have been used to create an engaging and inviting learning environment in large enrolment lectures (Lowery, 2005, Voelkel and Bennett, 2014, Jain and Farley, 2012, Zhu and Urhahne, 2018, Dabbour, 2016, Dabbour, 2017, Lyubartseva, 2013, Salemi, 2009). Polling and voting technology have evolved from devices and systems hardwired into classrooms to smart-phone based web applications that can be used in face-to-face, as well as online, learning environments.

Poll Everywhere, an online service for classroom response and audience response system using mobile phone technology (Shon and Smith, 2011), was implemented throughout Stream 1 of CVEN2401. Polling exercises involved:

- **Simple feedback surveys** – Students could comment on the difficulty of the content and provide suggestions to improve the delivery of lectures. Though this occurred during lectures informally, systemization through the platform allowed for enhanced documentation and transparency, fundamental to effective blended-learning applications (Chicca and Shellenbarger, 2018, Rahman, 2017). This feature conveyed to the cohort that the subject is adaptive and tailored to the needs of the students whilst also providing useful immediate feedback for the educators to continually improve delivery.
- **Choice tasks** – This was a generalized activity integrated into the lecture delivery. The tasks were designed to explain utility theory, introduce logit models and inform students of the importance of accurately measuring mode choice. Students had to select a mode for travel to campus based on a series of attributes. The attributes were included one at a time to illustrate the effect of each attribute on a user's choice of travel mode. Thorne (2003), (Bersin, 2004) and more recently Xie et al. (2019) provided evidence for the development of the choice tasks. The publications highlight the positive outcomes of enhanced information retention resulting from personalized choice tasks.
- **In-Class Game** – A real-time game was developed to present the theory of User Equilibrium (UE) in traffic assignment. A simple three route network with a single origin-destination pair and relevant travel cost functions were presented to the class. Each student in the class was then asked the question: *"Which route would you select?"* The students selected a route through the poll, the travel

costs were computed live in the lecture for each route, and the game was repeated over a number of iterations. The layout of the game is presented in **Figure 1**. Students would gain an understanding of computing travel costs for routes over many iterations. Students would swap routes until all users have an approximately equal (and minimum) travel cost, clearly highlighting the principle of UE. This game was developed extending the findings and lessons learned by Zhu et al. (2010). Similar to ADAM, this converted a complex principle into a computer- based exercise. However, through gamification it included an additional dimension to aid students to first understand and then retain information as a result of the experience within the game (Ding et al., 2017).

The lecturer embedded the polling exercises within PowerPoint presentations to deliver course material. To participate, students would enter a link accessing the relevant poll on their smartphone device and respond within the link, or text the response using a phone number, associated with the poll. Overall, from a teaching experience, the polling exercises required time to develop but were simple to implement using the commercial software. It offered an opportunity to interact with the students and reduced the monotony of a traditional large class lecture. In particular, the real-time feedback was invaluable in understanding deficiencies and improving the delivery of the material.

Online Quizzes

Assessment is a key aspect of tertiary education and effective learning (Gikandi et al., 2011). Literature suggests that teaching and learning processes need to be ‘assessment-focused’ to ensure that students have the opportunity to demonstrate their understanding and receive feedback and support to enhance their learning (Council, 2000). The large scale of the class suggested conventional in-class testing was not feasible and as such continuous assessment across Stream 1 of CVEN2401 was conducted using online formative assessments in the form of weekly online quizzes.

The quizzes were developed within the Moodle learning management system, the system used for all UNSW subjects, hosting all information related to the course including lecture notes, workshop problems and other relevant resources. Weekly quizzes contained three to five questions related to the material presented in the respective weeks lecture, they covered the topics of: Traffic Flow Theory, Queuing Theory, Trip Generation, Trip Distribution and Mode Choice. Multiple choice questions, true-false questions and fundamental short-answer calculation questions were included in each of the online quizzes. Given that the quizzes were developed on the standard learning management system, implementation and grading was straightforward. The most significant advantage for the lecturer with regard to the online quizzes implemented in CVEN2401 was gaining knowledge of students' understanding of the material prior to delivering the following weeks' lecture. Boitshwarelo et al. (2017) explains that effective online quizzes are very useful for both students and educators, especially in the delivery of foundational knowledge, included in CVEN2401. The lecturer and demonstrators of the course had the opportunity to clarify any points of confusion students had in a timely fashion thus reducing the number of students losing traction in achieving the learning objectives.

Practice-Based Road Design Assignment

Civil Engineering, like all other Engineering disciplines, is practical in nature. Students graduating are expected to work in teams, solve problems, manage projects and meet the needs of all relevant stakeholders in the community. Though traditional teaching approaches may provide the necessary theoretical understanding for a student, it is evident that project-based and problem-based assessments are vital in developing a professionally competent Engineering graduate (Mills and Treagust, 2003, Melin et al., 2010, Nicholas et al., 2003, Lo and Hew, 2019).

As discussed earlier in the paper, the difficulty in coordinating and implementing a project-based exercise is the large class environment. Enrolment of 40 students can be divided into 20 pairs where each pair completes the project as a team; this can be easily managed by the instructor. However, with CVEN2401, an enrolment in excess of 350 students presents a host of complexities in terms of forming and managing teams, tending to student queries which vary considerably given the realistic nature of the project and ultimately assessing reporting and presentation deliverables that are common outputs of such assessments. Volkov and Volkov (2015) explain the benefits of group-based learning in tertiary education, especially in terms of developing “job-ready” graduates, however, assessment design is critical to avoid the issues of free-riders in groups and provide fairness in grading. Though these challenges exist, a practice-based road design assignment was developed for Stream 2 of CVEN2401. The project format is essential for a comprehensive understanding of the interrelationships within the topic of geometric design. Furthermore, students were provided with an assessment task that involved report writing and the development of technical drawings, fundamental skills as practitioners.

In 2017, students formed teams of two or three students to undertake a redesign of an existing road section at the boundary of the UNSW campus. The road, Barker Street, is a historical road and had considerable safety issues in its state at the time. The teams needed to organize a site visit to understand the deficiencies of Barker Street and develop and present preliminary design solutions to overcome these deficiencies. In 2018, the project context changed where students were required to design a new road in the South West of Sydney as part of an expansion of the road network in light of the new Western Sydney Airport development. Autodesk design software, Infraworks 360 (now Infraworks) was used by students as a modelling tool to determine issues of the existing infrastructure as well as test design solutions to ensure a safe and economical design. Output from the software was then used by students as quantitative evidence in a project report and to develop technical drawings which presented the optimal solution.

The complexity of the project required careful planning and implementation of the project in the large class environment. Group selection was managed and maintained using an application within the Moodle learning management system. As with the online quizzes, utilization of the Moodle system streamlined group management and grading. Teams could easily communicate with one another on the platform and organize meetings to manage the project using the available chat features. In addition, a discussion forum was also made available. Students across the cohort could ask questions related to lecture material and project progress, which the lecturer and senior demonstrators monitored to help resolve any common obstacles. This project not only introduced students to the application of newly learned technical material presented in the lectures but also exposed them to new software. In order to ease the workload and technical aspects involved in learning new software, the teaching staff selected software that offered a vast amount of online support, Autodesk Infraworks, to ensure independent learning was achievable. Furthermore, weekly consultations were held by the lecturer and senior demonstrators to address any other concerns or questions raised by the cohort. Assessment of the project was structured using clear marking guidelines for the report and drawings which mapped back to the learning outcomes of the subject. In addition, teams were asked to provide a “Project Management Statement” used for peer assessment to ensure that all members of a team provided input in the final deliverables, as an attempt to mitigate the issue of free-riding within groups (Volkov and Volkov, 2015). The marking guidelines and system were included within the online framework to ensure consistency in the marking of the reports and technical drawings presented by each team.

The implementation of the project-based assessment was a logistical challenge. However, the challenge was overcome through features of Moodle and the use of an intuitive design software, Infraworks. Selection of less user-friendly software with limited support would have restricted the success of the initiative significantly. Similar to the online quizzes and interactive lectures, this project offered an opportunity for the lecturer to understand gaps in learning on a continuous basis because students would question the application of the theory from the context of the project. In this case, the project was a rewarding teaching tool within an introductory Engineering course from both a practical assessment perspective as well as a means of monitoring understanding across the weeks of lecturing.

Supplemental video material

Supplemental videos were included across the entirety of CVEN2401 to provide an additional source of revision for the students as well as enhancing the lecture presentations in Stream 2. The provision of supplementary videos have been emphasized in literature as beneficial to the learning experience, especially in large class environments (Houston and Lin, 2012, Ljubojevic et al., 2014). Videos have been used to flip classrooms by providing short pre-recorded videos of theoretical content which students review prior to attending class and then participating in active problem solving learning within the lecture period (Houston and Lin, 2012). Videos have also been found useful in enhancing student engagement and information retention when placed strategically within face-to-face lectures (Ljubojevic et al., 2014).

Over the years, feedback within Engineering courses consistently reveal that students desire greater exposure to worked examples. However, the time limitations of lectures and workshops make it difficult to cover enough examples to satisfy student expectations. Accordingly, a set of 12 worked examples were prepared using the “Explain Everything” software, covering a variety of topics covered within CVEN2401. The videos included a hand-written presentation of complex examples. The videos were as short as eight minutes for the easier examples, and as long as 20 minutes for the more difficult examples which provided detailed reasoning for calculations. In addition, three simulation videos were developed to enhance lecture material for the road design component of the course. These videos provided a three-dimensional presentation of the three key elements of Stream 2, Horizontal Alignment, Vertical Alignment and Earthworks. These videos were aimed to consolidate the two-dimensional presentation of calculations and processes. All videos were made publicly available through a YouTube channel dedicated to learning about transport organized by the authors.

Developing and recording videos was a time-intensive exercise, however having recorded explanations of fundamental concepts and examples has been an invaluable resource when explaining concepts. These positive teaching experiences are consistent with the descriptions presented in Rahman (2017) and Ljubojevic et al. (2014). The lecturers could refer to the supplementary videos during lectures and focus on more active learning exercises, such as the polling exercises or discussing road construction practices using real-world examples. Finally, it is important to mention that these videos are available on YouTube under the channel RCITI UNSW, thus allowing for global access (Research Centre for Integrated Transport Innovation UNSW, 2022). Viewership of videos that were posted during the research study varies from 1,500 views to 31,000 views, where detailed worked solutions to problems have greater numbers of views. This may indicate that students review the procedural content multiple times to appreciate the methodology, similar to recipes and other instructional videos, while theoretical content and explanations may not be repeatedly viewed. However, as these videos were posted for global access, the above viewership figures are not controlled within the study group and further studies regarding cohort- based viewership should be conducted.

It is evident that the development of the blended learning initiatives eased delivering material to students, offered a wider and more practical learning experience and provided a suite of supplementary material. However, the value of these initiatives is dictated by student satisfaction and the ability to showcase their understanding of assessable tasks. A comparison of the student feedback and performance between 2016 and 2017 is presented in the next section. It should be emphasized that the comparison presented does not quantify or evaluate the effectiveness of the learning initiatives developed. Instead, it utilizes the available course data (student feedback and performance outcomes) to provide further evidence of the impact of the transformation experience.

Effects on student reception and performance

The enrolment statistics for CVEN2401 over the duration of the study were: 386 students in 2016, 469 students in 2017 (an increase of 21.5% from 2016) and 504 students in 2018 (an increase of 7.5% from 2017). The similarity in enrolment sizes and the classification of a 'large class size' across the years of analysis means feedback and performance of the 2016, 2017 and 2018 cohorts can be compared qualitatively to gauge the impacts of the blended learning initiatives. Student feedback was gathered from the end of semester evaluations. During 2016, the UNSW Course and Teaching Evaluation Improvement (CATEI) system was used to survey students. This system was updated to the UNSW myExperience survey in 2017. Overall, both these systems asked similar questions; however, the UNSW myExperience survey was conducted online while CATEI surveys were conducted using pen and paper, which is the primary difference between the systems.

Student Reception and Feedback

Student feedback was gathered through a non-compulsory student feedback survey system. Response rates as a proportion of enrolments were similar across the years all exceeding the minimum of 10% (2016 – 17.4%, 2017 – 26.6%, 2018 – 31.8%) which was comparable to all other large class size undergraduate courses taught within the School of Civil and

Environmental Engineering at UNSW, and is deemed as a valid representation of student perceptions in the qualitative context of this study. As described in Section 3, due to the implementation of the blended learning initiatives, the CVEN2401 delivery mechanism in 2016 was significantly different from an assessment and delivery perspective to the course delivered in 2017 and 2018. The motivation for these adjustments to the course stems from the student feedback provided in 2016. The following themes were highlighted through a number of written responses gathered during the end of semester survey about features of CVEN2401 that could be improved.

- **Lack of personal and continuous feedback**: A number of students felt that there was a lack of assessments that offered an opportunity for continuous learning. Comments such as, "*more feedback needed throughout the course*" and "*add more assessments like weekly quizzes for greater levels of feedback*" were common. This led to the inclusion of the **weekly online quizzes** for Stream 1.
- **Difficulty in understanding the value of the course:** A few students also commented on the purpose and meaning of the course, feeling that they had gained nothing from undertaking it. This can be seen with the following response: "*Lack of assistance in doing worked problems. I generally find this course as pointless and I am only doing it cause its compulsory*". In a similar tone, there were also a number of students who were bored and uninterred with the material, reflected in comments such as: "*Needs to be more engaging content is too dry*". The desire for more interacting and engaging lectures, motivated the development of **interactive lectures** with in-class polling and games.
- **Disconnect between workshops, lecture material and assessments for the Road Design Component:** In 2016, the road design component was assessed using theoretical questions where students needed to calculate features of a road design,

similar to what students face in a final exam. The workshops were aimed to develop practical road design skills of applying the calculations to complete a realistic design and construct technical drawings. Even though the intention was to present the true application of theoretical concepts, many students felt that the workshops had no link to the course content. Statements similar to this were documented: "*Tutorials (workshops) felt quite irrelevant with respect to assessments at times, particularly the first road design workshop where we had to measure and draw the road*". Thus, the **practice-based road design assignment** was formed to better connect lectures and workshops whilst adding practicality to the assessment task.

- **More examples**: A number of students requested more worked examples: "*Give much more examples for us to prepare for the final exam, and provide much more useful examples related to the final exam*". Accordingly, the **supplemental video material** was created for greater examples and an opportunity for self-paced learning.

Post-implementation of blended learning initiatives in 2017 resulted in reduced demand for examples (though there were still a handful of students that requested even more examples) and overall positive comments in relation to the changes. Comments related to each initiative are presented in **Table 2**. Most importantly, there was an absence of any comments related to the connectivity of the material in Stream 2 or any reference to the lack of value of the course. This positive outcome is consistent with the findings of Rahman (2017), Zhu et al. (2010) and Alkhatib (2018) which suggest that blended learning provides a multi-dimensional offering for students, resulting in a greater appreciation of the material delivered.

There were differences in the feedback provided between 2017 and 2018. In 2017, the novelty of the supplemental video material and online quizzes resulted in more positive feedback for the resources as compared with 2018 students who came into the subject with expectations that those resources would be present. In 2018, in addition to commending the lecturers, on the interactive content and practical assignment, there were multiple comments of gratitude for the demonstrators that presented and assisted in the workshops. Comments included:

- "*Our tutors were great. Really helped me understand the course.*"
- "*Tutors knew what they were teaching the majority of the time*"
- "*Tutorial sessions with small groups, made it easier to ask questions and seek guidance on concepts that were not clear.*"
- "*Tutorials were very good as they went through examples and it's because of the tutorials that I feel most prepared for exams and I know what to expect.*"

This was somewhat of an expected outcome as the demonstration team included a majority of students who had either taught in 2017, thus having prior experience with the new delivery format, or were themselves students of the subject in 2017. The comments convey two key points regarding teaching large class sizes in Engineering; 1) students value opportunities to interact in smaller groups which can be facilitated in workshop/tutorial environments, and, 2) the tutors or demonstrators can enhance the learning experience provided they are confident and knowledgeable. Workshops throughout this subject served as a venue for practical application and exposure to real-world scenarios, thus effective guidance in these workshops resulted in greater satisfaction levels throughout the student cohort. This is consistent with findings from Ellis et al. (2008) and Kirn and Benson (2018), which imply the need for engineering students to have real world experiences to effectively learn the complex fundamental concepts.

It is important to note that both the 2017 and 2018 student groups provided suggestions for further improvements and modifications of the course and the new initiatives. Though students appreciated the quizzes and polling exercises, there was a desire for more detailed feedback. Accordingly, greater feedback was provided through a discussion forum and within the online platform in 2018 which reduced the instances for further explanations in the 2018 feedback. In addition, due to the popularity of the quizzes, they were included within Stream 2 as a means of continuous assessment.

In Stream 2, students felt that though a considerable effort was placed in providing resources to understand and learn Infraworks, more guidance could have been provided for using the software. This aspect was improved in 2018 with further documentation provided; however, there were still a large number of students who felt overwhelmed with the task based on the 2018 feedback. Accordingly, more tailored Infraworks instructional videos have been proposed to help learn the software in Stream 2. Frustration was expressed about the lack of experience in report writing resulting in poor performance; however, this was not unexpected as it was meant to be a challenging task for students in a group environment.

In order to provide a comparison between the 2016, 2017 and 2018 student groups, the mean ratings from the course surveys are presented in **Table 3**. Surveys, involved students to provide a rating for each question considering the following options: strongly disagree (1), disagree (2), moderately disagree (3), moderately agree (4), agree (5), strongly agree (6). The maximum rating possible is 6, and in general average ratings for lower-level undergraduate courses in the Faculty of Engineering vary between 4 and 5.

As mentioned earlier, the participation rates across the years were similar and they were deemed adequate sample sizes based on UNSW policy. It should be noted that the wording and number of questions presented to students changed from 2016 to 2017/2018 as a result of the change in systems, thus **Table 3** presents similar questions across all three years.

Table 3 shows minor improvements in the areas of feedback provision, active learning, course organization and the overall satisfaction of the course. Students were less satisfied in

2017 in terms of the assessments, however this dip improved in 2018 with slightly higher ratings. This is not an unexpected result as most students have an expectation about the structure of a course based on reviews of previous cohorts. Since the course was made more challenging with the introduction of project-based experiential learning and weekly online quizzes, students were moderately dissatisfied with the assessments of the course. However, the rating is still satisfactory as it lies between 4 and 5, indicating most students agree with the presentation of the course in 2017; this performance rating also aligns with the values of most first and second year undergraduate courses.

Student Performance

Performance across assessment tasks provides another indicator of the impacts of the blended learning initiatives. **Table 4** and **Figure 2** present student performance across assessment tasks for 2016 and 2017. Overall, the performance is quite similar between the years. There is a reduction in marks obtained by students when comparing Stream 2 assessments. This is understandable as 2016 offered numerical questions in a traditional assignment where students were marked only on the correctness of the solution. In 2017, in addition to technical questions, students were assessed on the justification of solutions, project management, report writing and presentation; skills that need further development. A number of students excelled in the project, but as discussed in Section 4.1, there were students who struggled to understand and apply these key skills necessary as a practicing Engineer. Midsession exam performance deteriorated significantly between 2017 and 2018 (median value reduced from 74% to 64%), which was not observed between 2016 and 2017. There is no clear reasoning for the deterioration in the performance of this assessment task and it could be a contextual reason as a result of competing workloads for that particular cohort.

The standard deviation of marks across all assessments reduced in 2017 and reduced further in 2018, indicating that a greater proportion of students understood the material but may not have excelled in their comprehension. This is further reflected in the lower average and median values for the course totals in 2017 and 2018.

The sentiment of moderated performance is reflected in the grading of the students presented in **Figure 2. Figure 2(a)** indicates similar course failure rates of around 5%, but a much lower proportion of High Distinctions in 2017 and 2018, between 9% and 15% less than 2016. Failure of the Final Exam reduced by 12.1% in 2017, as shown in **Figure 2(b)** potentially indicating that the blended learning initiatives provided enhanced foundational learning. However, this was not maintained in 2018, where there was only a 2% reduction of failure rate from the base value in 2016.

It is clear that these performance results are by no means conclusive, there are differences in the caliber of students between cohorts, the exam questions and assessment tasks were not identical and as such only a general qualitative comparison can be made. However, it is evident that the blended learning initiatives did not deteriorate student performance. From an educator's perspective, the blended learning initiatives provided the following key benefits:

- Opportunity to obtain more interaction within lectures allowing the educator to offer tailored and adaptive lessons suitable for the cohort's knowledge. This has been observed in previous studies such as Bodnar et al. (2016) and (Brown et al., 2013)
- Greater content coverage is feasible in the "flipped" environment as students are expected to learn foundational material in their own time which provides more time to apply knowledge within formal classes and workshops. Without the initiatives being implemented the flipped environment would not have been possible. In line with the evidence provided in Lo and Hew (2019), CVEN2401 students indicated positive perceptions towards the flipped learning initiatives reflected through the satisfaction surveys and stable performance.

- Visible student satisfaction and enthusiasm made the subject easier to teach for the lecturers. CVEN2401 is a core subject within the Civil Engineering curriculum at UNSW and as such not all students strive to work within the transport discipline. The blended learning initiatives assisted most in capturing the interests of all students, not only the students who had a passion for Transport Engineering. This was clearly evident in the engagement during the assignment for Stream 2 and also interactions within the discussion forum throughout the subject. Enthusiastic student engagement will provide further motivation for the educator to teach and improve the delivery of the subject.

Blending initiatives within CVEN2401 resulted in a feasible and meaningful teaching experience, especially in a large class size setting which resulted in favorable student feedback. However, it is important to note that further comprehensive research is necessary to quantify and validate the experiences described in this paper. Controlled experiments, detailed surveying of students and teachers and statistical analysis of feedback and results are important future steps. These steps can utilize the overarching experiences presented in this study to evaluate the costs and benefits of blended learning applications.

Conclusion

CVEN2401: Sustainable Transport and Highway Design, is a second-year introductory transport engineering course for undergraduate students at the University of New South Wales. This course is delivered in a large class environment and suffers the common issues of lack of personalization and a dependency on formal lecture- based teaching to the masses. This paper presents a reflection on a series of blended learning initiatives which includes: Online Quizzes, Interactive Polling, Practice Based Design Assignment and Supplementary online Video material, which were implemented into CVEN2401 during 2017 to improve the course. The new initiatives were well received by students, who appreciate the engagement and multi-dimensional resources offered. From an educator's perspective, the greatest benefit of the blended learning initiatives was the ability to deliver personalized, interactive and practical material in a large class environment that would not have been possible without blending the course. Furthermore, controlled experiments and statistically oriented research studies are necessary to quantify impacts and derive conclusive results; however, this study can be used as a case study of implementation that would be valuable to future applications of blended learning. In future, large class sizes are inevitable for tertiary institutions and based on the experiences documented in this paper, the development of blended learning approaches will be essential to provide quality education for Engineering students.

Data Availability Statement

All data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

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Manuscript Tables

Table 1. Summary of Blended Learning Initiatives.

Initiative	Objective	Technology Utilised
Interactive Lectures: **Real-Time in-class polling and feedback**	• Through the use of polling software, develop games and exercises to engage students in the subject matter, to enhance their learning, understanding, and retention during lectures. • Provide feedback to the instructor on the level of understanding of the students and also recording lecture attendance, which is difficult in a large class.	• Poll Everywhere.
Online Quizzes	• Weekly online quizzes during Stream 1 (weeks 1 to 6) to provide continuous assessment and feedback for the students.	• Moodle Quizzes.
Practice Based Road Design Assignment: **Group project assessment using industry specific software.**	• Provide students insights into the procedures and considerations necessary to redesign a road in Australia. • Students understand the interrelated nature of horizontal alignment, vertical alignment and earthworks in a real-time and simulated environment. • Students can: learn new software used throughout industry, work together in a group environment and develop report writing and presentation skills through the assessment task.	• Autodesk: Infraworks.
Supplemental video material	• Provide additional example problems, worked out step-by-step with voice over recordings for students to revise independently.	• Explain Everything.
	• Provide supplementary video recorded lectures to explain example problems and key concepts for students to revise independently	• Professionally developed animated videos.

Table 2. Select survey comments regarding the blended learning initiatives.

Initiative	Quotes
Interactive Lectures: **Real-Time in-class polling and feedback**	• *"Doing worked examples with students allowing interactive learning" (2017)* • *"Interesting content and interactive lessons were the best feature of the course" (2017)* • *"The lecturers for this course were very good, they presented the content well and were clear and easy to understand. They made the course relatively engaging and interesting" (2018)* • *"Both lecturers were clear and engaging, I believe they did a great job of presenting the course" (2018)*
Online Quizzes	• *"The online Moodle quizzes are really good at recapping everything the weeks lectures and keeping me up to date with coursework." (2017)* • *"…the transport quizzes were good at consolidating theory." (2017)* • *"I thought that the small weekly quizzes were really great ways to keep on track and updated on relevant coursework." (2017)* • *"The weekly quizzes really helped my understanding." (2018)*
Practice Based Road Design Assignment: **Group project assessment using industry specific software.**	• *"Overall great idea with the assignment" (2017)* • *"Going through the examples during the classes and lectures was really good. He was really active on the Moodle page and providing support and feedback. Good lecturer."(2017)* • *"The geometric design assignment was good, it nicely blended theory work with real life applications and taught us about using Autodesk Infraworks, an industry recognised software." (2017)* • *"…Assignment was also intriguing and very relevant. Being able to design the road allowed us to be able to achieve a greater understanding of how calculations and certain factors affect the road design." (2018)* • *"…The more hands on stuff with infraworks was the best…" (2018)*
Supplemental video material	• *"Provided extra resources online which were very helpful." (2017)* • *"Very clear, hand worked examples." (2017)* • *"Having all the material and extra material available online to revise was great." (2017)* • *"Plenty of worked examples to practice and learn from."(2017)* • *"Consistent practice questions to help learn the content" (2018)*

Table 3. Comparison of course satisfaction ratings.

Survey Question (2016)	2016 Mean Rating	Survey Question (2017,2018)	2017 Mean Rating	2018 Mean Rating	Discussion
I was given helpful feedback on how I was going in the course	4.21	**The feedback helped me learn.**	4.56	4.48	The improvement can be attributed to the implementation of the weekly online quizzes in 2017. The quizzes were automatically marked, student performance was revealed with the correct answers as feedback.
The course provided effective opportunities for active student participation in learning activities	4.48	**I felt part of a learning community.**	4.70	4.56	The improvement can be attributed to the introduction of class polling and interactive games within lectures. The activity offered greater interaction between the lecturer and students where the lecturer could immediately resolve gaps in overall understanding of the student group.
I was provided with clear information about the assessment requirements for this course.	4.75	**The assessment tasks were appropriate.**	4.35	4.47	The reduction in rating is likely to be due to the change in the structure of course assessments and the increased complexity of completing a group activity involving new software, which was not present in 2016. It will be necessary to trial the assessment structure over more semesters to understand if this is a reaction to change or a flaw in the modified assessment plan.
The assessment methods and tasks in this course were appropriate given the course aims.	4.84				
In this course the content is organized and presented in a logical and coherent way.	4.55	**Overall, I was satisfied with the quality of the teaching.**	4.67	4.70	Students were generally more satisfied with the course content, organization and presentation. This is likely due to the combination of blended initiatives spread across the entire course. By blending the course, it offered a more streamlined set of lectures and workshops and students could acquire fundamental concepts in the form of self-paced learning.
Lecturer/s handouts are a valuable aid to learning.	4.48				
Overall, I was satisfied with the quality of this course.	4.54	**Overall, I was satisfied with the quality of the course.**	4.59	4.53	

Table 4. Student performance across assessment tasks for 2016, 2017 and 2018.

		Assessment Weighting	**Average (%)**	**Median (%)**	**Standard Deviation (%)**
2016	Mid-semester Exam (Stream 1)	25.0%	73.6	76.0	16.8
	Assignment 1 (Stream 2)	12.5%	88.0	95.0	19.0
	Assignment 2 (Stream 2)	12.5%	90.8	96.0	19.7
	Final Exam (Stream 1 + 2)	50.0%	62.3	64.0	17.7
	Course Total	100.0%	71.8	73.5	15.0
2017	Online Quizzes (Stream 1)	5.0%	80.7	86.7	19.0
	Mid-semester Exam (Stream 1)	20.0%	73.9	76.9	16.8
	Assignment (Stream 2)	25.0%	79.3	83.0	16.4
	Final (Stream 1 + 2)	50.0%	61.9	63.0	14.8
	Course Total	100.0%	69.4	71.5	13.0
2018	Online Quizzes (Stream 1 + 2)	10.0%	83.1	86.7	14.7
	Mid-semester Exam (Stream 1)	20.0%	63.4	62.5	15.9
	Assignment (Stream 2)	20.0%	83.9	86.0	10.9
	Final (Stream 1 + 2)	50.0%	61.7	61.5	16.0
	Course Total	100.0%	68.6	68.7	11.2