Implementation of team-teaching in a large class through a Flipped Learning Approach for an Engineering Design Unit

Mohd-Zulhilmi Ismadi[1], Lim Jen Nee Jones[1] and Scott Wordley[2].
[1] School of Engineering, Monash University Malaysia, Jalan Lagoon Selatan, 47500 Bandar Sunway, Selangor, MALAYSIA, [2] Department of Mechanical and Aerospace Engineering, Monash University, Clayton, VIC 3800, AUSTRALIA.
Corresponding Author Email: mohd.zulhilmi@monash.edu

STRUCTURED ABSTRACT

CONTEXT
Flipped classroom has been proven to improve students' learning experience and attainment of designated outcomes. Since its full adoption in 2014 for a second year Mechanical Engineering unit, Engineering Design I, students are required to watch videos and complete online quizzes prior to a face-to-face activity in both University's Clayton and Malaysia campuses. With the increasing number of students in the Malaysia campus, it was found that the student satisfaction median score as well as the average final exam mark were declining for the past few years where workshops were taught by a single staff member. Compared to the Clayton campus, the satisfaction score was more stable despite the large number of students enrolled in the unit where workshops were supervised by at least two staff.

PURPOSE
This study is aimed at determining the effectiveness of a team-teaching approach within a flipped classroom for an engineering design unit to cater for different pace among learners. It is hypothesised that team-teaching improves students' learning by providing personalized attention for slower-pace learners while maintaining the overall coherency and motivation for fast-pace learners in face-to-face activities.

APPROACH
In 2018, team-teaching was adopted in the Malaysia campus in a two-hour workshop-style lecture hosting 154 students in a single auditorium every week. In team-teaching, one teaching staff member facilitates the activity while another two staff assist students who struggle or may have questions. The university's student evaluation score and students' final exam marks were used to measure students' satisfaction and attainment of the unit's outcomes for comparison with historical data.

RESULTS
Since the implementation of team-teaching in the past semester, students showed improved content-mastery in the formative and ongoing assessments compared to previous years. The improved student-teacher interaction in the workshop showed a positive impact on students' learning environment within the flipped classroom workshop. It was shown that the quantitative measurements in terms of students' satisfaction and final exam score has improved with the implementation of team-teaching.

CONCLUSIONS
Flipped classroom alone is not enough to mitigate the effects of increasing class sizes on student satisfaction and outcomes. Team-teaching in a flipped environment face-to-face activity re-focusses the student-teacher personalised interaction while maintaining the overall coherence of the subject, thus enabling a student-centred classroom more conducive to learning

KEYWORDS
Flipped classroom, team teaching

Introduction

The integration of technology in teaching and learning activities is gaining popularity in education providers. The rapid technological advancement results in increasing affordability and access to technological devices among students, thus allowing the creation of twenty-first century classrooms. This effort is aimed at improving students' learning environment and experience through highly-engaging activities (Hofstein and Lunetta, 2004) inside and outside of the classroom.

Unlike the traditional lecture delivery where the learning primarily revolves around the teacher within the classroom, flipped classroom focusses on the learners. In flipped classrooms, delivery of teaching materials can be done independently outside of the classroom through online content, in the form of video lectures, online discussions and articles available online (Abeysekera and Dawson, 2015). With the content delivery completed prior to the face-to-face classroom session, engaging activities such as active, collaborative, peer-assisted and problem-based learning can be conducted in-class that further construct and strengthen students' knowledge and understanding (Felder and Brent, 2003). As the students actively participate in learning activities, more time can be spent in developing students' higher order of thinking skills, such as design and problem solving with the assistance of their peers in groupwork and guidance from the teachers (Abeysekera and Dawson, 2015). Flipped classroom allows more personalised teacher-learner interaction especially in providing constructive feedback during learning phase (Danker, 2015). The shift of focus, through various types of activities, has been adopted in many institutions around the world.

The improvements in students' learning experience and measured learning outcomes have been proven in previous studies (Bishop & Verleger, 2013; Freeman et al., 2014; Love et al., 2014). In a study conducted in Pennsylvania State University, 75% of the respondents rated that their understanding of concepts was improved through problem solving activities in class and 48% of the students preferred using face-to-face class for similar activities (Zappe et al., 2009). Through the implementation of student-centric classroom, average students scored significantly higher in the assessments compared to similar-performing students in traditional class delivery (Freeman et al., 2014; Mason, Shuman and Cook, 2013). This scenario proves that flipped learning activities, along with personalised interaction are more effective in constructing students' knowledge compared to traditional lecture (Bryson and Hand, 2007).

Team-teaching is a method where more than one teacher collaboratively teach and coordinate learning activities. By having more teachers in the class, it improves student-teacher ratio thus allowing more interaction between the teachers and learners. As learners have different learning pace, team teaching enables slower-pace students to be given special attention without disturbing the flow of the classroom activities (Yanamandram and Noble, 2006). Furthermore, the diversity of qualities in terms of experience, communication skills and teaching style among teachers may complement each other while demonstrating effective teamwork, for the benefits of the students.

On top of the benefits to the students, team teaching has also shown to improve the quality of teaching with different styles of teaching become complementary. Through interactive team teaching, teachers can experience the best practice from good teachers that will improve their teaching skills (Letterman and Dugan, 2004; Baeten and Simons, 2014). Furthermore, it allows the teacher to be more focused on delivery or interaction while seeing different perspectives in the content.

Context

Engineering Design I is a core, second-year unit for Mechanical, Aerospace and Mechatronics Engineering programs. The unit emphasises design fundamentals and processes, technical drawing and Computer Aided Design (CAD) tools. Additionally, the unit includes a major design competition where the students are required to design, build and test their prototypes based on the requirements set by National Committee on Engineering Design for the annual Weir-Warman competition (Clucas, Wheeler and Smith, 2018). The learning outcomes for the unit are shown below:

- Apply appropriate design techniques such as problem definition, decision making, manufacturing processes and technical drawings according to AS1100;
- Select and use appropriate software & hardware to design & build a simple prototype mechanism;
- Document & communicate design process of a simple prototype mechanism; and
- Illustrate mechanical components and assembly of a mechanism using computer-aided drawing & design tools.

Teamwork, hands-on design and CAD components in developing solutions for complex engineering problems are the integral components in fulfilling Engineers Australia Stage 1 competencies (Engineers Australia, 2016). As one of Washington Accord accredited programs, Engineering Design I unit content is developed to fulfil three out of twelve graduate attributes and professional competency profiles (International Engineering Alliance, 2013) as follows:

- Design and development of solutions (WA3);
- Modern tools application (WA5); and
- Effective communication (WA10).

From 2014 to recent offering in 2018, a flipped approach was adopted with the number of enrolled students varying between 240 to 330 in Clayton campus and 100 to 165 in Malaysia campus. Pre-class activities include reviewing recorded videos and marked online quizzes as part of the continuous assessments. Students are given two attempts to complete the weekly quiz within 20 minutes prior to attending the workshop session. After completing the pre-class activities, students are also required to complete accompanying worksheets in a two-hour workshop every week, conducted in a lecture theatre. In the workshop session, teaching staff demonstrates the work activity and students are required to apply the concepts to solve the problems provided on hardcopy worksheets.

Tutorial sessions are allocated for the students to engage with the teaching staff to seek clarifications, advice and receive personalised feedback for their work. The students' work includes weekly worksheet task as well as Weir-Warman design progress. As most of the students attend the tutorial sessions with complete or near-complete answer and well-formed questions, the practice has allowed the teaching staff to give instantaneous feedback and guidance as corrective measure that strengthens the students' understanding of the content during knowledge the construction phase. Misunderstanding of the study content can be corrected early and improve the students' learning ability in a more advanced topic.

The adoption of flipped learning in the unit since 2014 has shown positive improvement compared to traditional class delivery prior to 2014. Student satisfaction median score in Clayton campus rose significantly from 3.91 (out of 5) to 4.73 in 2013 and 2014, respectively. However, as the class size increases over the past four years (from 104 to 165), the student satisfaction median score has declined in Malaysia campus from 4.39 (out of 5) to 3.89 where workshop facilitation was conducted by a single teaching staff. Prior to 2018, despite the adoption of flipped classroom, the demonstration of the workshop and its setting mimic a traditional lecture. With the growing number of students in the workshop, it was challenging for one teaching staff to facilitate multiple enquiries at one time, which possibly contributes to the decline of student satisfaction survey. Furthermore, the average final exam mark has also dropped, which reflects the students' decreasing outcome attainment. Conversely, the satisfaction score was more stable in Clayton campus despite having larger number of students enrolled in the unit. Unlike in Malaysia campus, the workshops in Clayton campus were facilitated by at least two teaching staff, and more recently up to four. The discrepancy between both campuses satisfaction score was hypothesised to be related to the number of staff facilitating the workshops. Thus, in 2018 offering, team teaching was introduced in workshop sessions in Malaysia campus.

This study is aimed at determining the effectiveness of a team-teaching approach within a flipped classroom for an engineering design unit to cater for different pacing among learners. It is anticipated that team-teaching improves students' learning by providing personalized attention for slower-paced learners while maintaining the overall coherency and motivation for fast-pace learners in face-to-face activities.

Methodology

In the 2018 offering, workshop sessions were conducted by three teaching staff in Malaysia campus, hosting 154 students. One teaching staff was tasked to lead the in-class activities, facilitate the overall flow and conduct the demonstration in the lecture theatre. The remaining two teaching staff were responsible to walk around the theatre and assist struggling students or answer their questions. The delivery of tutorial sessions remained similar to previous offerings to eliminate discrepancy and ensure validity of historical comparison in this study.

At the end of the semester, a standard university's teaching evaluation survey were distributed and completed by the students anonymously. A 5-point Likert scale was provided for respondents to quantify their level of agreement with each statement. The survey statements assessed the students' agreement in the knowledge and skills building, assessments and learning activities. The students' satisfaction score, where team teaching was implemented, was then compared with historical data and the score

obtained in Clayton counterparts. Open-ended comment sections were available to give the respondents the opportunity to provide detailed feedbacks and suggestions to the teaching model.

On the other hand, in assessing the attainment of students' learning outcome, final exam marks were used as primary indicator. These marks were compared with historical data by assuming the difficulty of the questions are relatively similar every year.

Results and Discussions

Students Satisfaction Survey

At the end of each semester, students are required to complete Monash University's teaching evaluation surveys that reflects their satisfaction and acceptance level of the unit delivery and teaching model. The survey provides useful quantitative and qualitative feedback for the unit coordinator to improve the delivery in the next offering.

Table 1: Median Student's Satisfaction Score

	Clayton Campus (minimum 2 teaching staff)		**Malaysia Campus**	
Year	Number of students enrolled	Median Student Satisfaction Score (out of 5)	Number of students enrolled	Median Student Satisfaction Score (out of 5)
2014	248	4.73	104	4.39
2015	285	4.60	109	4.28
2016	271	4.78	154	4.25
2017	255	4.35	165	3.89
2018*	330	4.23	154*	4.24*

* team teaching with three staff was implemented

Table 1 shows the overall median score of the student's evaluation on the Engineering Design I unit from 2014 to 2018 for both campuses with response rates are consistently above 55% of class size. Since the full adoption of flipped learning environment in both campuses, the median scores for Clayton campus were consistently higher relative to Malaysia campus despite having a larger class size. Up until 2016, Clayton campus showed remarkable median scores with a minimum value of 4.60 out of 5 whereas Malaysia campus obtained scores of about 4.30 in average for half of the counterpart's class size. These data showed a clear indication that the number of teaching staff and class size have some implication to the students learning experience. As the flipped classroom environment and content matures over time, the median score in Malaysia campus continue to decline and reach the lowest value of 3.89 in 2017 with specific written feedback to improve the student-teacher interaction in workshops. The adoption of team teaching with three teaching staff in workshops in 2018 was primarily aimed at improving the interaction and this practice has improved the median score to 4.24. 81.9% of the total respondents rated agree and strongly agree, which is an 11% increment relative to 2017 rating. The 2018 Clayton campus results also showed a drop of student's satisfaction while hosting the largest class size with two teaching staff in a session. These results suggested that more teaching staff are required to be present in the class to enhance the students learning environment and experience.

In response to the statement, *"The activities helped me achieved the Learning Outcomes for the unit":* 85% of the respondents rated strongly agree and agree in 2018 compared to 77% respondents rated similar agreement in 2017. 39% respondents rated 5 points (strongly agree) in team teaching setting compared to 16% in the previous year. The shift of the score contributes to higher median score from 3.96 to 4.26 for this statement. It can be said that more students perceive that they were able to achieve the designated learning outcomes when team teaching was implemented.

More students agreed that team teaching improves their learning in weekly workshop sessions, as reflected by the improvement of median score in this section from 3.98 to 4.26. Such improvement was contributed by 83% of the respondents who rated agree and strongly agree, compared to 73.9% of

respondents in 2017. In response to the most useful component in the unit, 13 out of 46 written comments further emphasised the positive impact of the workshops as an integral component in this unit within team teaching environment. The improved student-centred workshop arrangements were reflected by a significant reduction in 'in-need of improvement' feedback section by the respondents.

Student Learning Outcomes

Similar pattern was also recorded in student learning outcomes, indicated through the final exam marks. The final exam contributes to 30% of the overall marks in Engineering Design I unit whereas the remaining 70% is allocated for continuous assessments in-semester. It should be noted that students may have passed the unit prior to the exam. Final exam questions are deemed in similar order of difficulties as they were tested thoroughly by teaching staff to ensure the content and difficulty were maintained throughout the year. This practice aims at reducing uncertainties for comparison purposes in this study. The blinded and unknown problems in final exam serve as a good test to determine student's outcome attainment and ability to apply the knowledge they have learned throughout the semester.

Table 2: Average and standard deviation of final exam marks in Malaysia campus

Year	Number of students enrolled	Average Final Exam mark (%)	Standard Deviation (%)
2014	104	52.1	17.5
2015	109	47.2	17.2
2016	154	45.3	14.9
2017	165	43.7	17.8
2018	154	53.8	16.7

Table 2 illustrates that team teaching has shown improvement in the average final exam marks by the students. 2014 is the year where flipped classroom was introduced for the first time in both campuses. Since 2015, the average final exam marks were consistently recorded below 50% and continue to decline to the lowest value of 43.7%. With the implementation of team teaching in 2018, there was a significant increase to 53.8%. The improved mean marks displayed that more students were able to perform better in blinded problems and meet the learning outcome objectives.

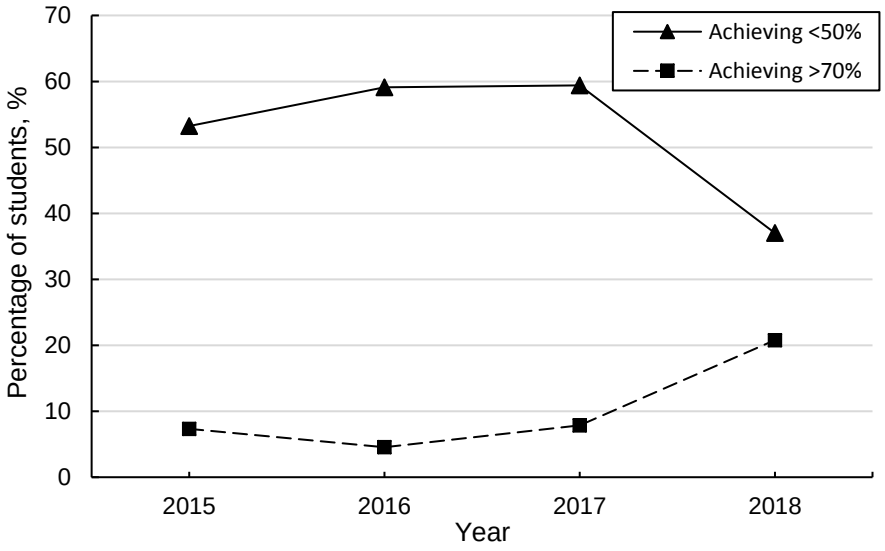

Figure 1: Students Exam Performance in Malaysia Campus

The implementation of team teaching has greatly reduced the number of students achieving below 50% marks and increased the number of students above 70% in final exam assessment as shown in Figure 1. In recent offering, 37% of the population were recorded to have obtained below 50% marks compared

to more than 53% in previous years. On the other hand, 20.8% of the class received more than 70% marks, a significant increment compared to about 7% in single teaching staff cohorts, which contributes to a higher overall average final exam mark in 2018. Students with slower learning pace were proven to be able to learn more effectively and solve unknown problems better through customised and personalised engagements in workshop session.

Conclusions

A flipped classroom was implemented in a core, second-year engineering design unit in 2014. Despite the wide acceptance of student-centred initiatives, the student satisfaction and outcome attainments continuously decline as the class size expands, particularly in Malaysia campus where the workshop was facilitated by single staff.

It has been shown that team-teaching in a flipped environment face-to-face activity re-focusses the student-teacher personalised interaction while maintaining the overall coherence of the subject, thus enabling a student-centred classroom more conducive to learning. The student satisfaction and workshop effectiveness ratings have improved in Malaysia campus to 4.24 and 4.26, respectively, with three teaching staff facilitating weekly workshop. Improvements in content-mastery have also been observed in final exam marks. In blinded unknown problems, more than 20% of the enrolled students were able to obtain distinction or higher compared to less than 10% in previous cohorts. Slower pace students were observed to benefit the most by the initiatives as the number of students getting less than 50% in final exam fall below 40%. These results highlight the importance of teaching staff number in the quality of interaction within large classroom. We have shown that thorough and personalised interaction improve students' outcome and learning experience by catering to different learners within the class.

References

Abeysekera, Lakmal, and Phillip Dawson (2015). "Motivation and cognitive load in the flipped classroom: definition, rationale and a call for research." Higher Education Research & Development 34(1), 1-14.

Baeten, M., & Simons, M. (2014). Student teachers' team teaching: Models, effects, and conditions for implementation. *Teaching and Teacher Education*, *41*, 92-110.

Bishop, J. L., & Verleger, M. A. (2013, June). The flipped classroom: A survey of the research. In *ASEE national conference proceedings, Atlanta, GA* (Vol. 30, No. 9, pp. 1-18).

Bryson, C., & Hand, L. (2007). The role of engagement in inspiring teaching and learning. *Innovations in education and teaching international*, *44*(4), 349-362.

Clucas, D., Wheeler, C., Smith, W. (2018) Project "PRAISE": Emergency Lift and Exchange of Volatile And Toxic E-waste. 31st Warman Design and Build Competition, Weir Minerals and Engineers Australia.

Danker, B. (2015). Using flipped classroom approach to explore deep learning in large classrooms. *IAFOR Journal of Education*, *3*(1), 171-186.

Engineers Australia (2014) Stage 1 Competency Standard for Professional Engineers. Engineers Australia.

Felder, R. M., & Brent, R. (2003). Designing and teaching courses to satisfy the ABET engineering criteria. *Journal of Engineering Education*, *92*(1), 7-25.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410-8415.

International Engineering Alliance (2013). Graduate Attributes and Professional Competencies. Retrieved from http://www.ieagreements.org/assets/Uploads/Documents/Policy/Graduate-Attributes-and-Professional-Competencies.pdf

Mason, G. S., Shuman, T. R., & Cook, K. E. (2013). Comparing the effectiveness of an inverted classroom to a traditional classroom in an upper-division engineering course. *IEEE Transactions on Education*, *56*(4), 430-435.

Hofstein, A., and Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education*, 88(1), 28-54.

Letterman, M. R., & Dugan, K. B. (2004). Team teaching a cross-disciplinary honors course: Preparation and development. *College teaching*, 76-79.

Love, B., Hodge, A., Grandgenett, N., & Swift, A. W. (2014). Student learning and perceptions in a flipped linear algebra course. *International Journal of Mathematical Education in Science and Technology*, *45*(3), 317-324.

Yanamandram, V., & Noble, G. (2006). Student experiences and perceptions of team-teaching in a large undergraduate class. *Journal of University Teaching & Learning Practice*, *3*(1), 6.

Zappe, S., Leicht, R., Messner, J., Litzinger, T., Woo Lee, H. (2009) *Flipping the Classroom to Explore Active Learning in a Large Undergraduate Course.* American Society for Engineering Education, Vol. 92, 2009.