EVIDENCE-BASED REFLECTIVE PRACTICE FOR ENGINEERING REPEAT STUDENTS IN FLIPPED LEARNING

Ying-Wei Leong

School of Mechanical & Aeronautical Engineering, Singapore Polytechnic, Singapore

ABSTRACT

This paper documents the author's application of reflective practice, to enhance quality teaching in a flipped learning context. The implementation of CDIO Standards was demonstrated in the aspects of teaching and learning techniques (Standard 8), faculty development (Standards 9 and 10), as well as assessment and evaluation (Standards 11 and 12). This was particularly evident in the enhancement of faculty teaching competence via evidence-based reflective practice (EBRP). To help an entire class of engineering repeat students to pass their repeat module and avoid expulsion, an EBRP tool was utilized. The tool originated from Singapore Polytechnic's Educational Development department and was subsequently customized by the author into a concise EBRP checklist suited for engineering schools. The 10 core principles of learning embedded in the EBRP checklist enhanced the repeat students' learning experience of their repeat module, via lessons delivered by the author. Coupled with its inherent evidence-based approach, the concise EBRP checklist acts like a structured template for a lecturer to quantify and enhance quality teaching. For data collection and analysis, a "crosshairs" methodology similar to the conventional "triangulation" was employed. The data input was by means of both qualitative and quantitative research paradigms. A "vertical line" was formed by two EBRP data points (qualitative), while a "horizontal line" was formed by two assessment data points (quantitative). Eventually, these lines intersect to form the crosshairs. The two EBRP data points were from both the lecturer and the student, whereas the two assessment data points consist of both formative and summative. Overall, the crosshairs methodology offers a widespread and balanced coverage for data collection and analysis. The tenet of every lecturer's pedagogical technique is to ensure their students achieve the learning outcomes and progress academically. The EBRP checklist used in conjunction with the crosshairs methodology yielded significant positive assessment results. Eventually, majority of the engineering repeat students (above 90%) benefited from the consequential enhanced quality teaching to pass their repeat module, avoiding expulsion and hence progress to their next academic phase of the education system.

KEYWORDS

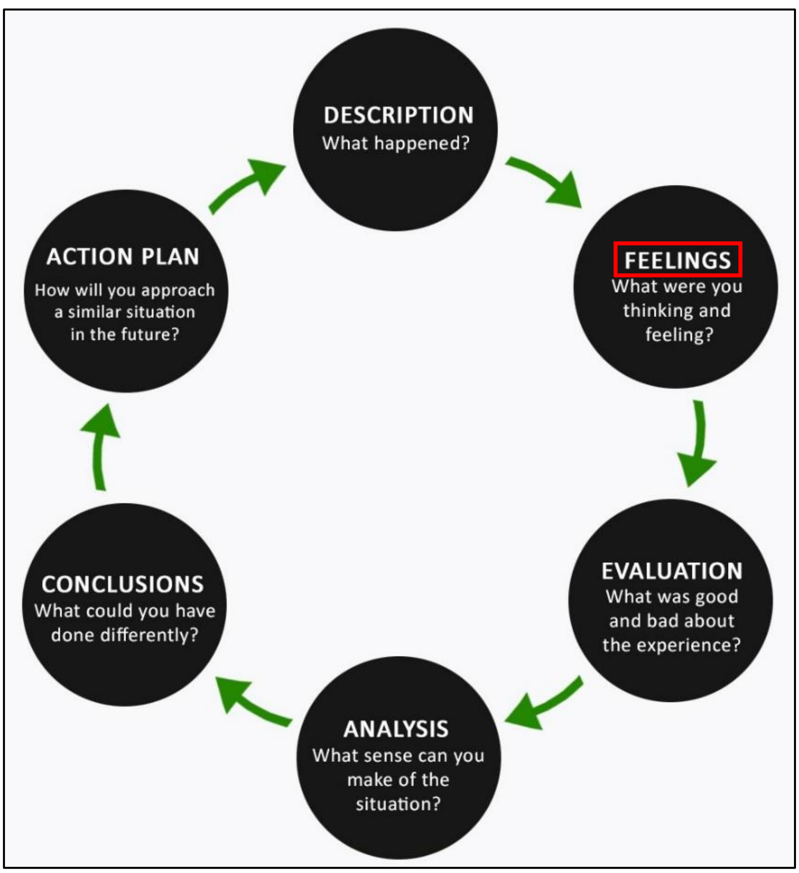
Evidence-Based, Reflective Practice, EBRP Checklist, Engineering, Repeat Students, Crosshairs, Flipped Learning, Standards: 8, 9, 10, 11, 12

INTRODUCTION

Reflective Practice

Reflective practice has long been applicable in various disciplines, especially in the field of pedagogy. It is commonly regarded as an individual's competency to reflect on his/her actions, in order to be in an iterative process of continuous learning through practice (Schön, 1983). Hence, it is a common habit among lecturers to maintain a teaching journal/portfolio which they update frequently, akin to an engineer's logbook.

One well-known model of reflective practice by Gibbs (1988) used in education is a closed-loop of 6 steps: description, feelings, evaluation, analysis, conclusions and action plan. Another model by Larrivee (2000) highlights the difficulty of good reflective practice, because a lecturer's response to a situation is filtered through 5 screens: past experiences, beliefs, assumptions and expectations, feelings and mood, personal agendas and aspirations. Generally, these popular educational models of reflective practice are inherently subjective as they involve content such as feelings and mood, as shown in Figure 1 below. They may not suit lecturers of science, technology, engineering and mathematics (STEM) schools, who are more accustomed to objective content like formulas and laws.



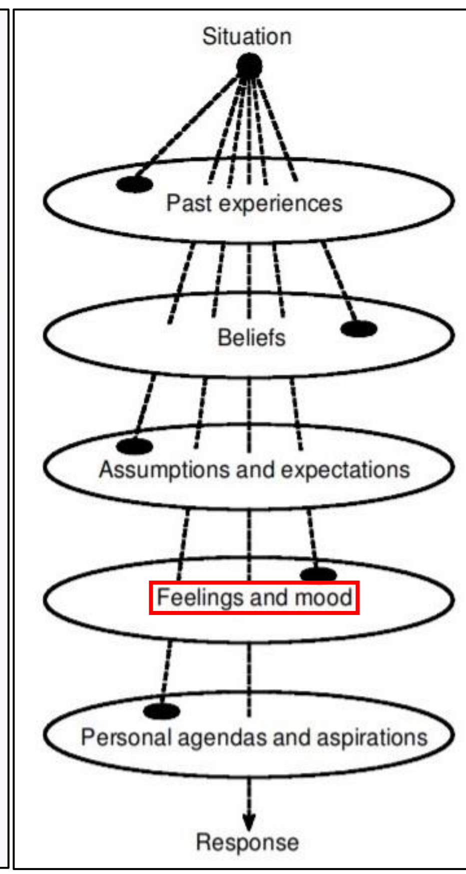


Figure 1. Reflective Practice Models by Gibbs (1988) on left & Larrivee (2000) on right.

Evidence-Based Reflective Practice Tool

One method to somewhat "measure" subjective reflective practice is by the inclusion of objective evidence.

In educational literature, it is highly recommended by researchers for good reflective practice used in education to be evidence-based (Hattie, 2008 & Sale, 2015). This is also applicable to engineering students in a flipped learning context (Sale et al., 2017 & Cheah et al., 2019). For nurses, evidence-based practice to improve patient outcomes via concrete evidence has been applicable since the 1800s by Florence Nightingale (Mackey et al., 2017). For lawyers, the strict compliance of the law of evidence is vital in all legal proceedings (Chen et al., 2018). Similarly for lecturers (such as of engineering schools), the utilization of an evidence-based reflective practice (EBRP) tool should be beneficial for pedagogy (Sale, 2020). To provide lecturers with some prediction of learning effectiveness before lesson and also diagnosis after lesson. EBRP aims to shed some light on how to quantify and enhance quality teaching, which is an ancient theme considered by some lecturers as "mystic arts".

To illuminate quality teaching, 10 core principles of learning (Standard 8) are embedded in the EBRP tool by Sale (2015 & 2020) to quantify quality teaching:

(1) *Learning goals, objectives & proficiency expectations are clearly visible to students.*
(2) *Students' prior knowledge is activated & connected to new learning.*
(3) *Content is organized around key concepts & principles that are fundamental to understanding the structure of a subject.*
(4) *Good thinking promotes the building of understanding.*
(5) *Learning is enhanced through multiple methods & presentation modes that engage the range of senses.*
(6) *Learning design utilizes the working of memory systems.*
(7) *Assessment is integrated into the learning design to provide quality feedback.*
(8) *The development of expertise requires deliberate practice.*
(9) *A psychological climate is created which is success orientated & fun.*
(10) *Motivational strategies are incorporated into the design of learning experiences.*

These core principles are all mutually inclusive and when used in conjunction with evidence of effectiveness to quantify quality teaching, they enhance quality teaching (Standard 10). Singapore Polytechnic (SP) introduced reflective practice as an annual performance goal for all academic staff in 2018/2019. The inception of this SP policy is to encourage lecturers to conduct reflective practice and even go further as action research (Toh et al., 2020), like this study (Standards 9 & 10). The EBRP tool by Sale (2020) was shared with Academic Mentors (including the author) of all the schools in SP, when he was Senior Education Advisor at the Educational Development department.

BACKGROUND

Flipped Learning Context

Diploma in Mechanical Engineering (DME) is the first such course in Singapore, with a history of 64 years to date and is the flagship diploma with the largest student cohort in SP School of Mechanical & Aeronautical Engineering (MAE). The author is MAE's Academic Mentor as well as the module coordinator of DME core module Thermofluids 1, which is taken by engineering students from 8 different SP courses.

Flipped learning gained immense popularity in the 2010s due to its self-directed approach (Bergmann et al., 2012) and is subsequently recognised as one of SP's educational initiatives (Leong et al., 2019). Thermofluids 1 is a flipped learning module, with online lessons available via SP's learning management system platform Blackboard and also PolyMall. PolyMall is a shared online portal developed jointly by the 5 polytechnics in Singapore, for their students and staff to access online learning content across various disciplines. On a weekly basis, students are instructed to study the e-learning content for preparation, before attending the lecturer's face-to-face lessons. Flipped learning and educational technology also proved to be essential during the coronavirus COVID-19 pandemic. To enforce social distancing, SP unprecedentedly shifted on-campus lessons to online, thus severely disrupting traditional teaching and learning.

Customized Evidence-Based Reflective Practice Checklist

In 2019/2020 semester 1, an entire class of Thermofluids 1 engineering repeat students was assigned to the module coordinator (the author), due to increased failures from the previous 2018/2019 semester 2. This class consisted of 18 Thermofluids 1 repeat students assembled from different MAE courses. If they fail their repeat module, they will be expelled from the school. It is feasible for EBRP to be applicable to engineering students in a flipped learning context, as documented by other SP academic staff (Sale et al., 2017 & Cheah et al., 2019). The author decided to utilize the EBRP tool by Sale (2020) to help his class of engineering repeat students to pass their repeat module and avoid expulsion.

The author customized the tool into a more concise EBRP checklist, such as by minimizing pedagogical jargons and adding numbered checkboxes for the 10 core principles of learning. Due to its inherent evidence-based approach, the concise EBRP checklist also acts like a structured template for a lecturer to quantify and enhance quality teaching (Standards 9 & 10). As a result, the EBRP checklist is suited for engineering schools who are more accustomed to objective content, especially tweaked for MAE.

This customized EBRP checklist was shared with MAE academic staff and lecturers generally found it easy to digest and use for reflective practice. MAE management also requested the author to conduct a formal sharing/training session for all staff in the near future, to help those with poor student feedback scores and those who face difficulties in doing reflective practice for their annual performance goals (Standard 12).

METHODOLOGY

In 2019/2020 semester 1, an entire class of Thermofluids 1 engineering repeat students was assigned to the module coordinator (the author), due to increased failures from the previous 2018/2019 semester 2. The focus group in this study's scope is this class of 18 Thermofluids 1 repeat students, assembled from different MAE courses. If they fail their repeat module, they will be expelled from the school. The author decided to utilize his customized EBRP checklist to help them to pass their repeat module and avoid expulsion. These repeat students were not taught by the author in the previous semester. Therefore, the key intervention process of this study was the author's lessons via his customized EBRP checklist throughout the following semester. This study's objective is to ascertain the effects of EBRP on the repeat students.

Crosshairs Data Collection & Analysis

For data collection and analysis, the author composed and employed an original "crosshairs" methodology, which is similar to the conventional "triangulation" (O'Donoghue et al., 2003). The data input was by means of both qualitative and quantitative research paradigms. A "vertical line" was formed by two EBRP data points (qualitative), while a "horizontal line" was formed by two assessment data points (quantitative). Eventually, these lines intersect to form the crosshairs. The two EBRP data points were from both lecturer and student, whereas the two assessment data points consist of both formative and summative. Overall, the crosshairs methodology "aims" to a widespread and balanced coverage for data collection and analysis. So as to obtain insightful information on the intervention from multiple perspectives. Refer to Figure 2 below for the crosshairs methodology.

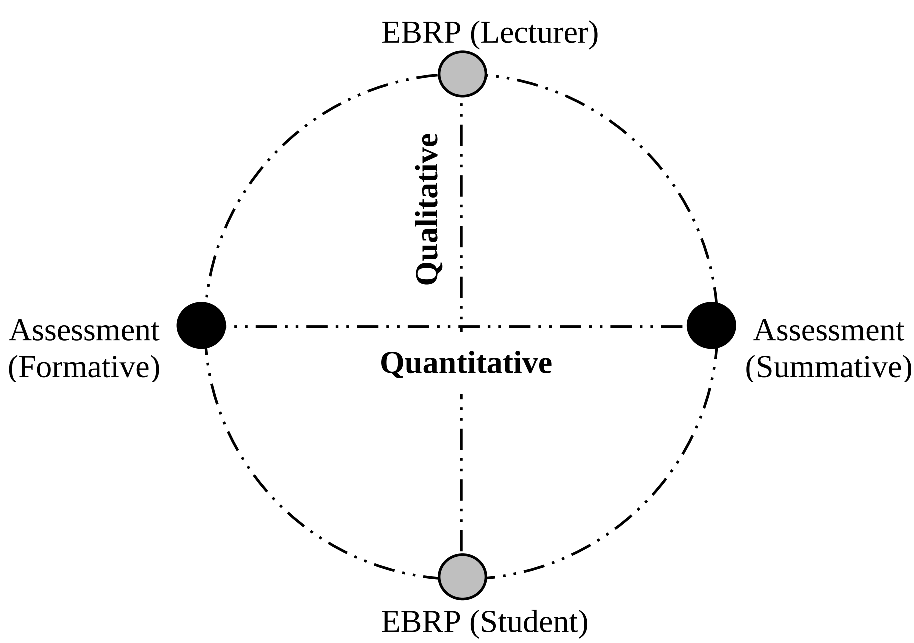


Figure 2. Crosshairs Methodology for Data Collection & Analysis.

For EBRP data points, the lecturer can be the teaching lecturer and/or another observer lecturer, while the student can be the learning student and/or another observer student. For assessment data points (Standard 11), the formative part can be the Mid-Semester Test (MST) and/or In-Course Assessment (ICA), while the summative part can be the Exam or End-Semester Test (EST).

Qualitative Data Collection & Analysis

For the qualitative aspects of this study, EBRP was done by the teaching lecturer (the author) and another MAE observer lecturer from Thermofluids 1 team, in addition to an observer student. The observer student was a former DME student invited to sit-in the lesson and use EBRP for student feedback. Being a recent graduate with perfect Grade Point Average (GPA) of 4, it would be insightful to note this student's opinions. Considering that this student also attended countless lessons by various lecturers from different schools in SP for the past 3 years.

Quantitative Data Collection & Analysis

For the quantitative aspects of this study, the formative assessment was the MST, while the summative assessment was the Exam. The class of Thermofluids 1 repeat students was not taught by the author in the previous semester. Therefore, the key intervention process was the author's lessons via his customized EBRP checklist throughout the following semester. Their Thermofluids 1 MST and Exam scores were compared for 2018/2019 semester 2 (pre-intervention) and 2019/2020 semester 1 (post-intervention), to obtain insightful information on students' achievement of learning outcomes.

According to the well-known educational research by Hattie (2008), formative evaluation to lecturers has a high effect size of 0.9, considering that the medium is only 0.4. This method is where lecturers take action to get formative feedback on their teaching and then act on it, which is similar to the author's intervention process and this study. There was ongoing evaluation of the author's lessons via his customized EBRP checklist throughout the semester, as EBRP can predict learning effectiveness before every lesson and diagnose after every lesson. This study also commenced during the first term of the semester, such that it is possible to tweak if necessary in the second term based on the MST scores' comparison.

RESULTS & DISCUSSION

Qualitative Data

For the qualitative aspects of this study, EBRP data were from the teaching lecturer (the author) and another MAE observer lecturer (Thermofluids 1 teaching team member), in addition to an observer student (DME recent graduate with perfect GPA). The EBRP checklist was used by the author for his lessons throughout the semester, as prediction of learning effectiveness before every lesson and/or diagnosis after every lesson.

Several noteworthy similar evidence of learning effectiveness were found in the EBRP data by the author, the observer lecturer and the observer student, for one of the author's pivotal lessons in the Thermofluids 1 syllabus:

- ✓ *All core principles of learning were attained.* After all, theses 10 core principles are all mutually inclusive and when used in conjunction with evidence of effectiveness to quantify quality teaching, they enhance quality teaching.
- ✓ *Opening summary of key concepts to enhance memory of both prior & new knowledge.* This corresponds to core principles 1, 2, 3 & 6.
- ✓ *Real-life examples (like Final Year Projects) to reinforce key principles & stimulate good thinking.* This corresponds to core principles 3, 4, 5, 6, 9 & 10.
- ✓ *Interesting variety in delivery methods (like videos) to maintain students' attention.* This corresponds to core principles 5, 9 & 10.
- ✓ *In-class questions-&-answers to ensure clear understanding before proceeding to next topic.* This corresponds to core principles 4 & 7.
- ✓ *Flipped learning online content for practice.* This corresponds to core principles 3 & 8.
- ✓ *Humour & reference to popular trends (like science-fiction movies) to engage students in a fun setting.* This corresponds to core principles 9 & 10.

The 10 core principles of learning by Sale (2015 & 2020) embedded in the EBRP checklist enhanced the repeat students' learning experience of their repeat module, via the author's lessons throughout the semester. On top of the focus group in this study's scope (which is the entire class of 18 repeat students from MAE), another 64 engineering students from SP were also taught by the author and benefited from the consequential enhanced quality teaching of EBRP too.

Quantitative Data

For the quantitative aspects of this study, assessment data were from the formative MST and the summative Exam. The Thermofluids 1 repeat students in the class were taught by other lecturers with no knowledge of EBRP in the previous semester. Therefore, the key intervention process was the author's lessons via his customized EBRP checklist throughout the following semester. Their Thermofluids 1 MST and Exam scores were compared for 2018/2019 semester 2 (pre-intervention) and 2019/2020 semester 1 (post-intervention), to obtain insightful information on students' achievement of learning outcomes. This study commenced during the first term of the semester, such that it is possible to tweak if necessary in the second term based on the MST scores' comparison. Refer to Table 1 below for the Thermofluids 1 MST scores' comparison of the 18 repeat students (anonymous).

Table 1. Thermofluids 1 MST Scores for Pre & Post Interventions.

	Student Name	Pre-Intervention (2018/19 S2) MST Dec2018	Post-Intervention (2019/20 S1) MST May2019
1	A	*ABSENT*	25/50
2	B	13/50	45/50
3	C	3/50	33.5/50
4	D	8/50	11/50
5	E	3.5/50	21.5/50
6	F	25.5/50	30.5/50
7	G	1/50	10.5/50
8	H	7/50	37/50
9	I	2/50	25/50
10	J	27.5/50	40.5/50
11	K	7/50	15.5/50
12	L	15/50	22.5/50
13	M	8/50	*ABSENT*
14	N	5/50	7/50
15	O	5/50	25/50
16	P	8/50	21/50
17	Q	8/50	23.5/50
18	R	14/50	14.5/50

The formative MST scores' comparison showed a significant positive trend after intervention. The average score improved by 30%, from 9/50 to 24/50 marks (rounded off to nearest whole number). Pre-intervention showed only 2 passes, but post-intervention showed 8 passes (including 2 grades of A). Based on the positive outcome of the formative MST, the author decided to continue delivering lessons via his customized EBRP checklist in the second term. This approach is akin to the high effect size method of formative evaluation to lecturers by Hattie (2008). In a hopeful attempt to prepare the 18 repeat students for the summative Exam and to help as many of them as possible to pass at the end of the semester.
Refer to Table 2 below for the Thermofluids 1 Exam scores' comparison of the 18 repeat students (anonymous), as well as their overall final grades after factoring in MST and ICA too

Table 2. Thermofluids 1 Exam Scores for Pre & Post Interventions, & Grades.

	Student Name	Pre-Intervention (2018/19 S2) Exam Feb2019	Post-Intervention (2019/20 S1) Exam Aug2019	Post-Intervention (2019/20 S1) Final Grade Sep2019
1	A	8/100	42/100	D-
2	B	17/100	71/100	B+
3	C	26/100	41/100	D+
4	D	12/100	46/100	D
5	E	22/100	40/100	D
6	F	16/100	41/100	D+
7	G	18/100	52/100	D
8	H	25/100	42/100	D+
9	I	27/100	47/100	D+
10	J	12/100	53/100	C+
11	K	15/100	*WITHDRAWN*	
12	L	25/100	35/100	D
13	M	7/100	*WITHDRAWN*	
14	N	8/100	29/100	F
15	O	10/100	44/100	D+
16	P	17/100	47/100	D+
17	Q	13/100	*ABSENT*	
18	R	26/100	52/100	D

The summative Exam scores' comparison also showed a significant positive trend after intervention. All repeat students who sat for the post-intervention Exam improved in their scores. Their average score improved by 28%, from 17/100 to 45/100 marks (rounded off to nearest whole number). For pre-intervention in the previous semester, all 18 of them failed based on overall final grades and hence repeated Thermofluids 1. Eventually for post-intervention in the following semester, only 1 repeat student in the entire class failed the repeat module and faced expulsion.

Repeat students have always been considered as at-risk students, who require lecturers' monitoring and intervention. The monitoring of engineering repeat students to predict their performance in a flipped learning context was studied by other SP academic staff (Kok-Mak et al., 2019). However, the intervention for such students lack studies that are backed by quantitative assessment data collected and analyzed accurately. Ideally, an accurate study should keep all variables constant, except the variable in the study's objective. National Aeronautics and Space Administration (NASA) compared the data of genetically identical twin astronauts (one was in space, while the other remained on Earth) over a year to accurately study the effects of space on humans (Garrett-Bakelman et al., 2019). Likewise, the author was given the unique opportunity to accurately study the effects of EBRP on the same 18 repeat students learning the same repeat module, via comparing their pre and post interventions' quantitative assessment data over 2 consecutive semesters.

REFLECTIONS & CONCLUSION

The EBRP checklist is a versatile educational instrument that can be utilized both as an intervention and also for data collection and analysis. A lecturer can use the EBRP checklist as prediction of learning effectiveness before lesson and as diagnosis after lesson. To shed light on the ancient theme on how to quantify and enhance quality teaching, hopefully enabling the lecturer to be a “master of the mystic arts”. Resembling survey and observation forms, the EBRP checklist can also be used by a lecturer for qualitative data collection and analysis.

Despite the many pros of the EBRP checklist, there exist some cons too. For instance, it is challenging to implement it for a module that has mostly hands-on practical lessons in a workshop (like DME’s Computer-Aided Machining). The workshop environment inherently limits the variety in delivery methods and media by the lecturer (core principle 5). All the online lessons delivered during the coronavirus COVID-19 pandemic also faced this same limitation of variety. Moreover, without on-campus physical interaction due to social distancing, it is not easy to engage and bond with the students (core principle 9). Thus, follow-up work in the near future shall involve modifying the EBRP checklist to have alternative versions for practical-heavy and online-heavy modules.

The tenet of every lecturer’s pedagogical technique is to ensure their students achieve the learning outcomes and progress academically. The author’s customized EBRP checklist used in conjunction with his original crosshairs methodology yielded significant positive assessment results. Eventually, majority of the engineering repeat students (93% based on post-intervention final grades) in the class benefited from the consequential enhanced quality teaching to pass their repeat module, avoiding expulsion and hence progress to their next academic phase of the education system.

The author received a handful of unsolicited appreciation emails from his repeat students, during the wee hours when final results were released for 2019/20 semester 1. The author hereby concludes this paper by sharing one such memorable email below, demonstrating the fruitful implementation of CDIO Standards (particularly Standard 10) via EBRP.

Morning Mr Leong,

I would like to say a really big thank you to you for making second chances feels like it is never the end of the line. Probably i have disappointed you by not being able to turn up some of your lectures and tutorials, but by all means, you are One of the Best Lecturer i have ever met. Making the class lively through your jokes and Marvel related way of learning things, is just something i will always appreciate until the end. Although my results is a D+, but i believe you have impacted me the most in terms of changing my learning habits. Once again, thank you for believing in us. I hope to see you around in school :)

Yours Sincerely,
Captain “6F” (anonymous)

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BIOGRAPHICAL INFORMATION

Ying-Wei Leong is the Academic Mentor in the School of Mechanical & Aeronautical Engineering (MAE), Singapore Polytechnic (SP). He is also the lead in course management of SP Diploma in Mechanical Engineering, the first such course in Singapore and the flagship diploma with the largest student cohort in MAE. He teaches engineering core modules like Thermofluids and Mechanics, and also supervises CDIO final year projects including an industry collaboration project that held a Guinness World Record.

Corresponding author

Mr Ying-Wei Leong
School of Mechanical & Aeronautical Engineering, Singapore Polytechnic, 500 Dover Road, Singapore 139651
leong_ying_wei@sp.edu.sg