# A DATA-DRIVEN APPROACH TO FLIPPED LEARNING FOR DIFFERENTIATED INSTRUCTION IN ELECTRONIC ENGINEERING

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## ABSTRACT

This paper documents an evaluation of a project that aimed to use a technology platform in a flipped learning format that generates student performance data to provide a differentiated learning environment. This project was focused on enhancing key aspects of the student learning experience, especially in relation to CDIO Standards 8: Active Learning and 11: Learning Assessment. The technology employed the Brightspace Learning Management System, especially the learning analytics features, to extract, collate, and present key performance data on online assessment in preparation for focused feedback and differentiated instructional activities in the face-to-face sessions. The scope of the implementation at the School of Electrical & Electronic Engineering (EEE) at Singapore Polytechnic (SP) involved 36 classes, 20 lecturers and 648 students. The methodology followed a broad Action Research approach that sought to understand how the initiative impacted the students learning experience, as well as how teaching faculty dealt with the challenges of the instructional approaches employed. The evaluation findings showed positive results on the use of the selected active learning methods (e.g., challenging questions, peer instruction, and differentiated learning activities). The design and use of the active learning methods reflected the integration of subject content with key critical thinking skills (e.g., analysis, evaluation) about the concepts the students were learning and their application in real work contexts. The importance of providing focused and timely feedback for enhancing student understanding was also supported in the data obtained. Future research will seek to incorporate emerging generative Artificial Intelligence (AI) tools that can further enhance SP's goal towards providing a holistic education underpinned by the CDIO framework.

**KEYWORDS**: Active learning, Differentiated instruction, EdTech, Standards 8, 11.

## INTRODUCTION AND CONTEXT

It was not that long ago that Petty (2009) argued that teaching was ready to:
...embark on a revolution, and like medicine, abandon both custom and practice and fashions and fads, to become evidence-based (cover page).

Certainly, we are rapidly increasing our knowledge relating to how humans learn, what teaching methods and practices work best, and why. The significant research on learning is well documented in the literature (e.g., Bransford, 1999; Marzano, 2007; Hattie, 2009, Hattie & Yates, 2014, Sale 2020). Collectively, the research evidence increasingly framed as Evidence-Based Teaching (EBT) is now providing us with a heightened pedagogic understanding of the various facets of highly effective teaching. In turn, this should lead to enhanced attainment and engagement opportunities for a wider range of student groups.

Furthermore, in the past decade or so, and especially resulting from the Covid-19 epidemic, technology-based learning formats such as online learning, blended learning, and flipped classroom learning have become increasingly popular as preferred delivered modes in many educational and training contexts. Ongoing research evidence suggests that blended learning formats are not only more efficient and flexible but also more effective than either face-to-face or fully online learning (e.g., Means, Toyama, Murphy, Bakia, & Jones, 2010; Abeysekera & Dawson, 2015; Shao & Liu, 2021).

More recently, *Learning Analytics* (LA) in learning management systems can collect, analyse, and present students' performance data in highly visual ways to enable both rapid and focused feedback and guide instructional interventions during face-to-face tutorial classes (e.g., Mian, Khalid, Qun & Ismail, 2022).

Moving forward with continually improving student learning, and with the progress made in EduTech tools, SP introduces the DEFL framework to bring together the use of flipped learning, EBT, ALeRT and learning analytics. SP has comprehensively employed flipped classroom learning (e.g., Sale, Cheah, & Wan, 2017). The acronym ALeRT stands for "Assessing Learning Regularly for Timely Support". Its implementation was documented in other papers (e.g., Wan & Chong, 2021; Wan et al., 2023). With this, SP hopes to provide more differentiated instructional activities through the ability to do real time assessment and provide timely and focused feedback to its students.

DEFL is essentially an EBT and EdTech blended intervention. In summary, it provides an integrated pedagogic approach that employs specific instructional strategies with technology affordances to enhance key aspects of the student learning experience. In the context of CDIO Standards, it focuses on 8: Active Learning and 11: Learning Assessment, but it also impacts other standards, as it involves considerations of learning outcomes, integration, faculty development, and program evaluation.

The summary of the DEFL Model is depicted in Figure 1 below. The key instruction process and features include:

a) Instruction on key subject content knowledge aligned to selected learning outcomes are delivered through asynchronous lectures.
b) Diagnostic testing of key concept knowledge. This assessment method is intentionally chosen to comprehensively evaluate both students' learning and identify potential gaps in understanding key concepts. This strategic selection aligns seamlessly with CDIO Standard

c) 11: Learning Assessment, emphasizing the importance of aligning assessment methods with learning outcomes.
d) Student differentiation based on performance in the pre-class tests, and allocation of students to activities for the face-to-face sessions.
e) A variety of active learning strategies such as group discussions, peer learning and two-way feedback are employed in the face-to-face sessions customized to students' needs based on the assessment data. CDIO Standard 8: Active Learning is deliberately and seamlessly implemented in face-to-face sessions.
f) Formative assessment (e.g., quiz) and feedback (CDIO Standard 11: Learning Assessment) are conducted after class to check the effectiveness of face-to-face sessions and the need for any follow-up.
g) Use Learning Analytics for ongoing insight into students' performance to guide future instructional activities.

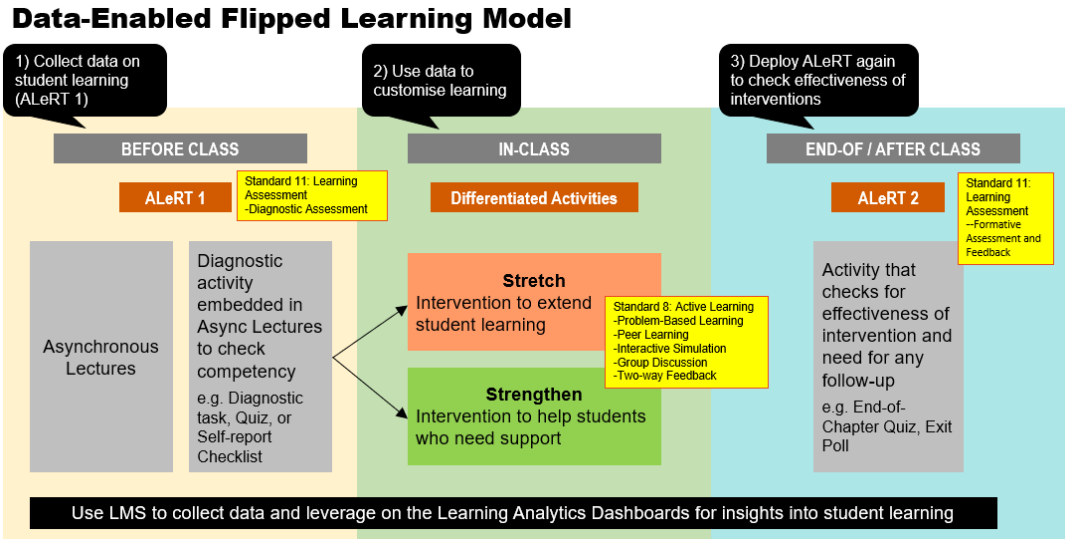


Figure 1. Data-Enabled Flipped Learning (DEFL) Model

The design and delivery of the DEFL is consistent with the application of the CDIO Framework, which is shown schematically in Figure 2, by making a simplified representation of DEFL shown in Figure 1 (Cheah, 2024):

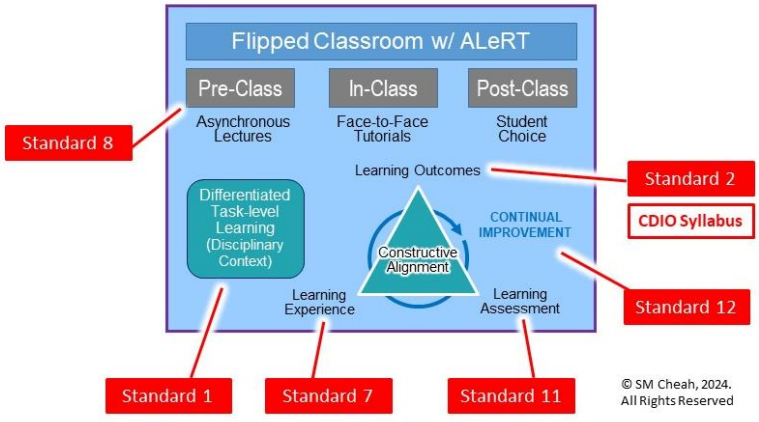


Figure 2. How CDIO Framework supports the application of DEFL (Cheah, 2024)

## RESEARCH OBJECTIVES

The broad research objectives focused on:

- How useful did students find the instructional format and approach employed (e.g., quizzes, learning activities, challenging questions, peer teaching) to support their learning (e.g., clarifying expectations, providing timely and supportive feedback, creating interest and challenge)?
- How did teaching faculty experience the initiative in terms of their professional role (e.g., able to identify student-specific learning gaps, gain better insights into student understanding to provide effective two-way feedback, and design and facilitate more differentiated and personalized instruction)?

## METHODOLOGY

The present initiative involved 36 classes of the Digital Electronics module (ET1004), in which 20 teaching faculty and 648 EEE students were involved in AY2022/23 Semester 2. The methodology was designed to capture specific aspects of the learning experience of both students and teaching faculty during the project intervention duration. The methodology involved collecting quantitative and qualitative data through a questionnaire, comprising fixed and open response items, tailored to the research goal and key questions. The questionnaire items were provided by the polytechnic's educational department for staff to evaluate the effectiveness of DEFL. The full questionnaire items are contained in Appendix A & B. In addition, separate focus group interviews with five staff were also conducted.

This paper followed the broad aims and process of action research (AR), which primarily seeks to understand better and improve practice – in this case, how a large-scale pedagogic intervention could enhance student learning for a wider student cohort. Quantitative analysis was used to collate student and staff responses to the fixed response items and facilitate the analysis and interpretation of this data. For the qualitative data, derived from the open-response items, a broad thematic coding approach was employed to identify, analyse, and interpret common patterns in the data (e.g., repeated/similar meaning responses) to frame main categories.

## RESULTS & ANALYSIS

### *The Student Learning Experience*

The summary data from the fixed response items in the student questionnaire are presented below in Figure 3. A total of 203 out of 648 students participated in the survey, resulting in a response rate of 31%.

Overall, the data suggest that students were positive about the various components of the initiative. The provision of variation in the learning activities, challenging goals, timely and helpful feedback, and clear expectations for learning are all congruent with research on what teaching methods work best. To illustrate, Feedback has an Effect Size of 0.73 and Challenging Goals, of 0.57 (Hattie, 2009). The relatively lower positive response for 'The learning activities assigned gave me confidence in my learning', is perhaps more difficult for students to answer as assessing one's confidence may be less easy than the other constructs provided.

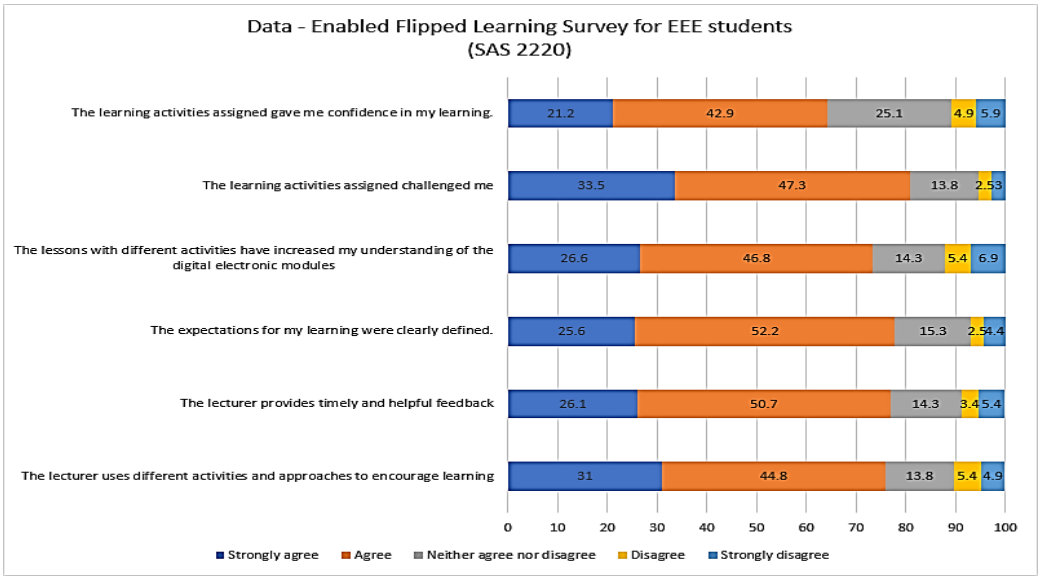


Figure 3. Data-Enabled Flipped Learning Survey for EEE Students

The data from the open response items focused on identifying:

- The 'muddiest' points of the module (topics requiring more clarification) (Q.7)
- Personal experience from doing this module (Q.8)
- What learning activities are most liked and why (Q.9)?

For Q.7, the only most notable area that the students found the 'muddiest' related to the understanding of Multiplexers and Demultiplexers; with 22 references to these concepts and their application. Tables 1 & 2 summarize the responses for Questions 8 & 9.

Table 1. Q.8 Personal experience from doing this module

| Category | Number of Responses |
|---|---|
| Positive (Good, Enriching, Fun) | 45 |
| Organized/Clear Explanation/Pace | 10 |
| Challenging tasks | 4 |
| Resources on Brightspace | 3 |

Table 2. Q.9 The learning activities most liked and why

| Category | Number of Responses |
|---|---|
| Challenging Questions | 39 |
| Peer Teaching | 38 |
| Class Presentations | 8 |
| Pre-class Quizzes | 4 |

A notable inference from the data is that the strategic blending of effective methods is important, as they seem to have a synergistic impact. This is consistent with the work of Hattie (2009) who used the analogy of a 'Russian Doll' to describe the process of combining several effective methods into the overall instructional strategy.

However, there were six responses of not liking the module, and one student specifically saw the peer teaching as not useful, as it led to some students doing all the work, while others were able to benefit without making a personal effort. Eight negative comments were recorded relating to the exit poll, captured by one student respondent:

“I don't think exit polls are useful since most of the time, I do it for the sake of completing it. Any questions I have I would ask in class or otherwise would be cleared up when going through pre-class quizzes or tutorial sessions.”

There was also variation in the perception of the instructional effectiveness of teaching faculties – many were very positive, while some were quite negative.

“My learning experience for this module is very fun and curious because the lecturer every time come out with new idea to teach us to understand better”

“Module was interesting, but the lecturer was not up to standard. I had to chase other lecturers for help.”

In summary, the findings on student learning experience showed positive results on the use of the selected active learning methods (e.g., challenging questions, peer teaching, and differentiated learning activities). The findings were consistent with Standard 8: Active learning, which emphasizes engaging students in thinking about the concepts they were learning and their application in real work contexts. The importance of providing both focused and timely feedback for enhancing student understanding were supported in the data obtained, consistent with CDIO Standard 11: Learning Assessment.

### *The Staff Learning Experience*

The summary data from the fixed response items in the staff questionnaire are presented below in Figure 4. A total of 12 out of 20 staff participated in the survey, resulting in a response rate of 60%.

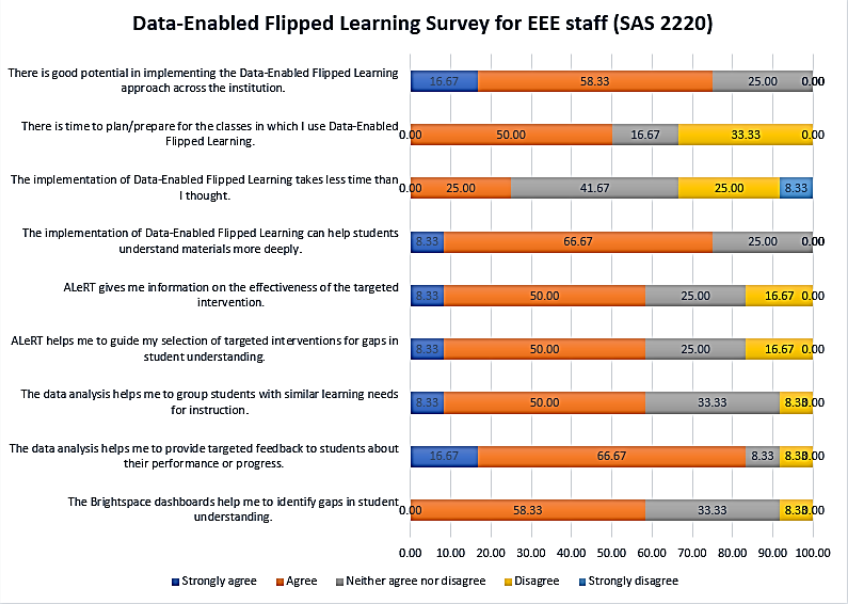


Figure 4. Data-Enabled Flipped Learning Survey for EEE Staff

The staff's response on the potential learning benefits of implementing the DEFL approach across SP can be described as positive, with 75% either strongly agreeing or agreeing. There is no response for disagreeing or strongly disagreeing. The highly favourable response for helping students to understand more deeply and provide targeted feedback (75% and 83.34%, respectively) seems to align with the student perceptions in these areas.

The main areas of disagreement or neither agree nor disagree relate to the time needed to plan instructions and implement the initiative (50% and 75%, respectively); notably, only 25% agree that the implementation takes less time than previously thought. The data from the open response items focused on identifying:

- The advantages and disadvantages of using the Data-Enabled Flipped Learning Approach (Q's 7 & 8 respectively)
- Their experiences in using the three learning designs, and suggestions for future improvement (Q.9)
- The support needed to adopt the approach (Q.10).

Tables 3 & 4 summarize the responses:

Table 3. Q.7: Advantages of using the DEFL Approach

| Category | Number of Responses |
|---|---|
| Understanding students' learning | 4 |
| Self-Directed Learning | 2 |
| Evaluate Instruction | 1 |

Table 4. Q.8: Disadvantages of using the DEFL Approach

| Category | Number of Responses |
|---|---|
| Time constraints | 2 |
| Limitation of Data Produced by Brightspace | 1 |
| Too few pre-class quizzes | 1 |

The most notable advantage was the ability to gain more precise insight into how students were learning the topics. This enabled them to better identify what has been learned, understand specific knowledge gaps, and provide further instructional direction. Students being given the opportunity to do work independently and develop self-directed learning skills was also seen as a positive outcome.

The main disadvantage related to the additional time needed to prepare instructional material. This was seen as time consuming and to use the words of one staff respondent, "Progress of teaching is slower". One respondent also highlighted the "need for statistics and data presentation for each class, not just the whole cohort which is the current situation in Brightspace. Without relevant data, it is meaningless to talk about the advantages of DEFL".
In terms of support needed to adopt DEFL, time was seen as the main concern, and two respondents specifically noted the need for more tutorial hours. Three other responses may be significant in terms of future planning:

"Flipped classroom learning takes too much time from teachers who may need more time to help weaker students."

“As we are doing self-directed learning, perhaps over time, the system can be built up in such a way that at the end of the pre-class quiz, the students with questions answered wrongly can be directed to the material that explains the concept right away.”

“I support it if the data provided is directly relevant and can be used immediately without the need to spend too much time analysing the data further.”

The focus group, involving five staff, reinforced the findings from the questionnaire. The capability to enhance student learning was noted, especially in relation to identifying students who needed support, and the variety of activities that seemed to engage most students. One respondent made the pertinent point: “I like the fact that we have deliberately designed active learning in the class.”

On the negative front, concerns about time and the perceived limitations of the present data analysis (as identified previously) were reiterated. Concerning time, one staff wrote:

“If I have to do all these things, I easily use up 25% of my 2 hours in class. 1/4 of the time is spent on all these things in the class, which is not productive.”

On the data analysis issue, staff wrote:

“…if you are not able to see the information by the class, then it is not useful for

the DEFL. It’s only useful for maybe the course review or coordinator.”

“I feel that there needs to be a way to make sure that the data being collected is accurate because even if you have data, if the data is not accurate, it’s pointless.”

In summary, the findings on staff’s experience were highly positive on DEFL's capability to enhance student learning and identify students who needed support. The main concerns on time and data analysis were noted. Specifically, to streamline and enhance the data analysis process for the new semester, the educational department has developed the DEFL dashboard, and the staff can filter the quiz data by class.

## IMPLICATIONS FOR PRACTICE & RECOMMENDATIONS

As the student and staff data is consistently positive about the initiative overall, as identified in the questionnaire and supported in the qualitative feedback, the implications now focus on how best to further enhance both the range of active learning methods employed, and support staff development in their capability to utilize and integrate them consistently in their practices.

To support staff development, the main recommendation is to develop what Hargreaves and Fullan (2012) refer to as ‘Professional Capital’ - that is to achieve institutional capability in applying DEFL effectively and efficiently across all courses in SP. As SP has a well-established CDIO framework, and a strong evidence-based pedagogy, DEFL is potentially highly scalable. This can be achieved as the format can be modelled and customized to different courses, and through the Poly wide network of academic leaders and strong learning community spirit.
At the level of professional development, staff can be encouraged to conduct further action research on implementing the key active learning and feedback methods employed. For example, the use of questioning, peer instruction, and setting challenging goals are all well

validated active learning methods in terms of enhancing learning outcomes (e.g., Hattie, 2009). This will further support wider CDIO progression, especially Standard 10: Enhancement of Faculty Teaching Competence, as it will require SP staff to ensure they have high levels of competence for creating, delivering, and improving these areas of practice in their courses.

## FUTURE DIRECTIONS

Future research will seek to employ statistical tests on pre and post data to establish the variation in outcomes generated, enhance aspects of the questionnaire design, and extend the implementation of AI technologies that positively impact the learning process. For example, this semester, we have employed a customized AI chatbot driven by generative AI that provides content to address the specific needs of individual students. It also enables ongoing precise prompt adjustments to make the learning process more effective and engaging for them.

## CONCLUSION

The research has contributed to a better understanding of how both students and faculty have experienced this intervention, which were the key objectives. It has demonstrated that from a well-established CDIO curriculum framework, we can now both further enhance students' learning experiences and faculty capability in providing quality and differentiation through emerging technologies.

## ACKNOWLEDGEMENT

We would like to extend gratitude to Dennis Sale and Cheah Sin Moh, experts in pedagogy, for their invaluable guidance. Their insights into evidence-based teaching methods and the implementation of CDIO standards have significantly enriched our research work.

## FINANCIAL SUPPORT ACKNOWLEDGEMENTS

The author(s) received no financial support for this work.

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## APPENDIX A

### DEFL Survey Questions for EEE Students

1. The lecturer uses different activities and approaches to encourage learning.
2. The lecturer provides timely and helpful feedback.
3. The expectations for my learning were clearly defined.
4. The lessons with different activities have increased my understanding of the digital electronic modules.
5. The learning activities assigned challenged me.
6. The learning activities assigned gave me confidence in my learning.
7. What muddiest point(s) about the module topics that you still need clarification on after going through the assigned learning activities.
8. Please share with us your learning experience for this module.
9. Which learning activities (e.g., challenging questions, peer teaching etc..) do you like the best and why?

## APPENDIX B

### DEFL Survey Questions for EEE Teaching Staff

1. Your perception of the data provided by the Brightspace visuals.
    a. The Brightspace dashboards help me to identify gaps in student understanding.
2. Your perception of data analysis for flipped learning.
    a. The data analysis helps me to provide targeted feedback to students about their performance or progress.
    b. The data analysis helps me to group students with similar learning needs for instruction.
3. Your perception of teaching strategies resulting from ALeRT.
    a. ALert helps me to guide my selected of targeted interventions for gaps in student understanding.
    b. ALeRT gives me information on the effectiveness of the targeted intervention.
4. Your perception of beliefs
    a. The implementation of DEFL can help students understand materials more deeply.
5. Your perception of time
    a. The implementation of DEFL takes less time than I thought.
    b. There is time to plan/prepare for the classes in which I use DEFL.
6. Your perception of potential
    a. There is good potential in implementing the DEFL approach across the institution.
7. What are the advantages of using the DEFL approach?
8. What are the disadvantages of using the DEFL approach?
9. How do you feel about the three learning designs? What changes would you make to make the lessons better?
10. What support do you need to adopt the DEFL approach?