

# Blended Learning to Enhanced Engineering Education using Flipped Classroom Approach: An Overview

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**Abstract** – The learning approach is always being the concern of educators to increase the quality of engineering education. Engineering education is essential in order to nurture quality engineers and prepare the workforce for country development. Coming to Industry 4.0, modern engineering education has combined ICT technology to meet the demand of Education 4.0. This paper aims to review blended learning to enhanced engineering education using flipped classroom approach. The paper starts with an overview of the current trend of engineering education, which encourages using blended learning approach. Blended learning was developed to overcome the advantages and disadvantages of traditional learning and online learning, which brings a better learning experience to students. From the review, the blended learning using flipped classroom approach have positively assisted students in their learning. Future ongoing research is recommended to explore the potential of flipped classroom approach use in supporting engineering education specifically in the context of Malaysia.

**Keywords** – *Blended learning; Flipped classroom; Engineering education*

## I. INTRODUCTION

Engineering education is a critical component of STEM (Science, Technology, Engineering and Mathematics) education. In accordance with the Malaysia Education Blueprint 2013-2025, it is essential to improve the standard of engineering education to realise the transformation shift of the education blueprint [1]. As stated in Massachusetts Institute of Technology's (MIT) New Engineering Education Transformation (NEET) report, the future plan of engineering education will be emerging and more focus to student-centred learning with the combination of off-campus personalised online learning and on-campus practical experience learning [2]. Such indication encourages for the using of blended learning pedagogy in engineering education.

The majority of modern engineering education combines conventional face-to-face class with online

learning. However, research indicates that the current teaching and learning strategy could not completely satisfy students' learning preferences [3]. A study of engineering education at Universiti Teknologi MARA (UiTM) Sarawak Malaysia reported that although traditional lecture-based teaching is still adopted in higher education institutions, there has been a movement in some institutions to shift from teacher-centred to student-centred learning, in which teachers serve as facilitators and students participate more proactively in their learning [4]. From a practical standpoint, engineering lecturers face a difficult task because they must devote time and effort to having a multi-faceted approach to teaching in order to appeal to students' various learning preferences. As a result, both engineering students and lecturers must be exposed to blended learning, a student-centred educational approach capable of diversifying the learning experience [5]–[7].

This paper will introduce the current trend of education pedagogy, which implements blended learning using flipped classroom approach in engineering education. The paper is structured as follows; Section II is the Engineering Education 4.0; Section III is the Engineering Education in Malaysia. Section IV describes about the Computer Aided Learning (CAL) in Engineering Education. Section V presents the Learning Approaches and Section VI discusses about the Blended Learning Approaches. Section VII is the Flipped Classroom Approach followed by Section VIII the Conclusion of this paper.

## II. ENGINEERING EDUCATION 4.0

### A. Engineering Education Paradigm

The earliest engineering education began in France. The first engineering school was established in Paris in 1747 [8]. A general view on the Engineering Education paradigm, the studies conclude that the shifting of the engineering education paradigm relates closely to the industrial revolution. The shifting from Industry 1.0 to 2.0

took almost a century and a half, the time between the industry 2.0 and 3.0 was a few decades, but the transition from industry 3.0 to 4.0 was much shorter than before. This shrinking of periods between transformations was caused by the pace of technological advancements [9]. Furthermore, the role of computer technology is getting essential in the industry and engineering education, especially in ICT (Information and Communication Technology), which brings a lot of convenience and improvement to engineering education.

During the era of Industry 3.0 and Industry 4.0, ICT (Information and Communication Technology) played an essential role in shifting the engineering education paradigm from passive learning to adaptive learning. The most obvious example is the way to gain knowledge. When students need some materials for their learning during the early days, they can only get it using the traditional way: either from the textbook, library, or lecturer. In this digitalised era, students can quickly gain their knowledge by connecting to the Internet, and it is faster and more convenient. In addition, the research added that digital multimedia technology like video, 3D animation, and AR (Augmented Reality) technology increase the interactive and visualisation level of students dealing with the information [10]. Another research by Wallner and Wagner further added that the teaching process could not be successful without the active involvement of students [11]. In order to prepare the student for the future, the education model should meet these criteria, including personalised learning, student-driven education, variety source to knowledge, setting for the classroom (online learning and face-to-face classroom).

Industry 4.0 is defined as integrating information and communication technology and industrial progress, aiming to develop intelligent factories to achieve more efficient, green, and customised manufacturing processes. In this era of innovation, industry 4.0 integrates new technologies, especially in the working environment, which is more utilise on ICT technology, improves productivity, and expands the market. Thus it creates a new professional image to meet the needs of consumers [12].

### B. Engineering Education 4.0

Research indicates that the upcoming industrial revolution, industry 4.0, and the following technology-driven changes have triggered great improvement in engineering education, especially Engineering Education 4.0 [13], [14]. In order to provide these new skills, universities are responsible to provide educational models, which will combine modern industrial technologies and principles; at the same time, it must help boost communication, be individualisation, collaboration, and related to social needs. Technology-enhanced learning provides this possibility by integrating online learning and technology to support the teaching and learning process.

A study summarises that five major shifts in engineering education have occurred during the past 100 years [15] that can be listed as following:

1. A shift from hands-on and practical emphasis to engineering science and analytical emphasis.
2. A shift to outcomes-based education and accreditation.
3. A shift to emphasising engineering design.

4. A shift to applying education, learning, and social-behavioural sciences research.
5. A shift to integrating information, computational, and communications technology in education.

The study indicates that the first two shifts already occurred while current engineering education is still in the process of the latter three-shift of the engineering education paradigm [15]. Furthermore, two researches presented the nine trends in Education 4.0 to cope with Industry 4.0 [12], [13].

1. **Flexible Schedule**

Learning occurs anywhere or anytime. Students learn according to their pace.

2. **Adaptive Learning Tool**

Students modify the learning tool according to their preferences and suitable for them. They can utilise different devices, programs, and technologies to keep them active learning but not blind learning.

3. **Personalise Learning Style**

The learning methods suitable for the student's conditions include accessibility, learning pace, base knowledge, and learning preferences.

4. **Student-centred**

A traditional classroom is more teacher-centred, where students rely more on a teacher to deliver the knowledge. Student-centred encourages the student to be more independent in the learning process. The lecturer acts as an instructor or facilitator in the classroom.

5. **Practical Application**

Educational institutions will provide students with more opportunities to acquire real-world skills that represent their work and provide students with internships, guidance projects, and cooperation projects.

6. **Project-based Learning**

Students must learn how to apply their organisation, teamwork, and time management skills to cope with various situations in a short time.

7. **Ownership**

Students are encouraged to design their courses according to their interests, and they can take the initiative to take part in their curricula planning.

8. **Evaluation Method**

The assessment will be based on the results such as the project, Question, and Answering (Q&A) session, not the examination.

9. **Data Interpretation**

The ability to interpret data is essential and critical in Industry 4.0, especially in this era of digitalisation.

Tertiary education is the last difficulty for engineering graduates before they move to the workplace. With the coming of Industry 4.0, the university should be responsible for preparing engineering graduates adapted to new technologies, equipped with solid fundamentals of engineering knowledge and excellent problem-solving skills. The research stressed that universities must take responsibility to provide students with the skills needed to effectively perform in the future industries. Therefore, the training for future engineers needs to be reformed [12].

### III. ENGINEERING EDUCATION IN MALAYSIA

#### A. *Engineering Education Accreditation in Malaysia*

The first engineering education in Malaysia began with the Engineering Department at the University of Malaya on the Singapore campus in 1956. The first Bachelor's Degree in Engineering Department was Civil Engineering. In 1958, the University of Malaya moved to Kuala Lumpur, and the second Bachelor of Mechanical Engineering program was started. At that time, the Engineering Department was upgraded to the Faculty of Engineering, with more engineering courses being introduced. Other public universities in Malaysia also expanded their engineering courses to meet the market demand. In addition, with the increasing growth of ICT technology in Malaysia, engineering education in Malaysia undergo a various transformations to meet the global marketplace [16].

Engineering as the professional course in Malaysia usually takes four years to complete. Engineering Certification Committee (EAC), established in 2000, is an organisation authorised by the Board of Engineer Malaysia (BEM), which is responsible for all accreditation activities for engineering degree programs provided by Malaysia [17]. Research by Soon and Quek further explained that, in order to maintain the quality of engineer graduates, the Board of Engineer Malaysia admit and manages the professional engineers, the Institution of Engineer Malaysia (IEM) provide continuous professional development, and the Malaysian Qualification Agency (MQA) responsible for certifying the engineering courses in Malaysian universities [16].

Over these years, to leading the professional and quality of Engineering Education in Malaysia, Bloom's Taxonomy and Outcome-Based Education (OBE) was implemented in the teaching and learning process. Bloom's Taxonomy and OBE are the standards and essential criteria were used by EAC and BEM to certified the Malaysia Engineering program [16]–[19]. Another research further explains that, according to the document experiences of an engineering faculty in Malaysia and the Engineering Accreditation of Malaysia in meeting the requirements of the Washington Accord sponsors and mentors, Outcome-Based Education is an essential requirement for full membership of the Accord [20].

#### B. *Malaysia Education Blueprint 2013-2025*

Align with the Malaysia Education Blueprint 2013-2025 (Preschool to Post-Secondary Education), the aspiration of the education system suggests 11 shifts of transformation to bring a better education system to Malaysian. Three shifts that will be highlighted in this paper which are:

*Shift 1: Provide equal access to quality education of an international standard*

One of the points that focus on this shift is strengthening the quality of Science, Technology,

Engineering, and Mathematics (STEM) education. As one of the crucial branches in STEM, engineering education plays a vital role in effect the aspiration of Malaysia Education Blueprint 2013-2025.

*Shift 7: Leverage ICT to scale up the quality learning across Malaysia*

Shift 7 encourages the Utilise the ICT technology in expanding the quality of teaching and learning experience, especially in augmented the online content to encourage self-paced learning to eliminate the time and location barrier, especially for non-urban or rural areas [1], [21].

*Shift 9: Implementation of Blended Learning in Higher Education Institutions, which help to provide a more individualised learning experience to the students*

The Shift 9 focus on globalised online learning. Blended learning models will become the primary teaching approach in all colleges and universities [22]. Students will benefit from the robust network infrastructure, supporting video conferencing, live broadcast, and Massive Open Online Courses (MOOCs). Malaysian higher education institutions will also develop MOOCs in their areas of expertise, participate in the international MOOCs alliance and build Malaysian education brands globally [23].

### IV. COMPUTER-AIDED LEARNING (CAL) IN ENGINEERING EDUCATION

With the arrival of Industry 4.0, the role of computers has become more important in engineering education. Due to the rapid increase in the number of students, the limitation of lecturing hours, the rise of information, the complexity of knowledge, the shortage of teachers, and the promotion of personalised learning, the necessity of using computers in education has increased rapidly. Besides that, the rapid development of computers has affected our education system. Computers have great potential in education through their interaction, vision, auditory, rapid calculation, storage, data retrieval, etc. [24]. In engineering education, the learners utilise computer technology in CAL (Computer-Aided Learning), CAD (Computer-Aided Designing), CAE (Computer-Aided Engineering) [25]. This paper will focus on Computer-Aided Learning.

Research claims that the engineering subjects are highly theoretical [26]. In traditional engineering education, the teaching method mainly is dominated by lecture-based and problem-solving exercises. In addition, with the emergence of engineering, collaboration with many research fields, causing a vast amount of information to increase tremendously. In addition, due to Industry 4.0, the skills required by engineers are getting higher; thus, it is challenging for universities to provide comprehensive courses for undergraduates only in 4 years.

Computers provide support and enhance engineering education in different implementation forms. Sidhu and Lee conclude the four ways that ICT (Information Communication Technology) can be adopted in engineering education [10] as listed in Table 1.

Table 1. ICT tools [10]

Tools/ Explanations	Examples/ Explanations	Examples of Development Tools/ Platforms
<p><b>Information tool</b> Provides a platform where deliver knowledge and instructions.</p>	<ul style="list-style-type: none"> <li>• <i>MOOC</i> Massive Open Online Course is one of the examples that utilise ICT technology as information. MOOC is a web-based class designed to support a large number of participants. MOOC brings advantages to the flipped classroom as it promotes self-regulated learning. With this platform, the student can preview the course material (video, slide, etc.) before class, study according to their pace. The flipped classroom concept is to flip the traditional classroom instruction style, in which instruction and course material will be given to students before class [27]–[29]. Lecturers can use MOOCs to track their students' progress and customise their instruction to meet their needs [30]. However, MOOC shows a low completion rate, which has been a common problem in online learning. Moreover, MOOC also results in low interaction between student and lecturer [27].</li> </ul>	<ul style="list-style-type: none"> <li>• Web Development Framework</li> </ul>
<p><b>Situating tool</b> Experience the complex engineering theory in real-life, simulation tools contribute better visualisation experiences to students and providing greater benefits to engineering education.</p>	<ul style="list-style-type: none"> <li>• <i>3D- Animation</i> Integration of animation into learning is an innovative teaching method that supplements traditional teaching methods. Previous studies have shown that computer animation supports and helps students understand intricate and complex concepts. 3D animation provides a similar representation of real objects in digital form. It can enhance students' understanding and prevent students from misunderstanding in the learning process. 3D animation allows learners to observe many phenomena, which are difficult or even impossible for them to observe in the real world [31].</li> </ul>	<ul style="list-style-type: none"> <li>• AutoCAD</li> <li>• SolidWorks</li> <li>• Blender</li> <li>• 3ds Max</li> </ul>
	<ul style="list-style-type: none"> <li>• <i>Augmented Reality</i> Augmented Reality (AR) superimposes virtual objects on real images captured via mobile devices. In educational settings, Augmented Reality (AR) is one of the newest visualisation technologies. For its visualisation features in encapsulating and showing complex or intangible content, augmented reality has been applied in various fields [32]. In manufacturing, AR can be used to see replicas of real devices, find specific problems, compare parts, and determine the specification. Hence, technicians can support or solve problems from anywhere [12].</li> </ul>	<ul style="list-style-type: none"> <li>• Vuforia Engine</li> <li>• Wikitude</li> <li>• ARKit</li> <li>• ARToolKit</li> <li>• ARCore</li> <li>• Adobe Aero</li> </ul>
	<ul style="list-style-type: none"> <li>• <i>Virtual Reality</i> Virtual reality technology can be used as a supplement to three-dimensional modelling. It helps students better understand the behaviour of objects and the consequences of the behaviour [33]. According to research, VR technology was commonly implemented in higher education, especially in the basic science and medicine domain, in order to provide more real interactive engagement with students [34]. Non-immersive VR and immersive VR (IVR) are the two types of virtual reality. The simulation is presented on desktop screens, enabling low levels of immersion in non-immersive VR, often known as desktop-based VR. Using head-mounted displays (HMD) or projection-based displays (PBD), IVR allows users to immerse themselves in virtual environments fully. [35].</li> </ul>	<ul style="list-style-type: none"> <li>• Blender</li> <li>• Google VR</li> <li>• OpenVR</li> <li>• Unity</li> </ul>
	<ul style="list-style-type: none"> <li>• <i>Computer Simulation Games</i> Using animation, graphics and multimedia technology, engineering topics can be designed to attract and motivate students in order to explain the course and build up problem-solving skills effectively. The combination of simulation software and games in computer simulation games can positively assist students in terms of enhancing their learning experiences by practical knowledge and the serious games well prepared by their lecturers [36]. Students are motivated to take personal responsibility for their decisions. Furthermore, the lecturer's role shifts from teacher to instructor. According to the example given by the research, several computer-based games have been developed in Engineering Mechanics. These games aim to cultivate students' fundamental concepts and basic calculation in statics and mechanics courses [26].</li> </ul>	<ul style="list-style-type: none"> <li>• Unity</li> <li>• CryENGINE</li> <li>• Godot</li> <li>• Unreal Engine</li> </ul>
<p><b>Constructive tool</b> Manipulate data and generate analysis</p>	<ul style="list-style-type: none"> <li>• <i>Cloud computing</i> Cloud computing uses Internet servers, which provide an accessible way to use computer resources, such as network, storage, applications, and various services. People can get resources from anywhere, provide real-time data. Besides that, cloud computing can perform big data analytics and deep learning and machine learning processes. The use of cloud computing help in collect, process, deliver and derive value from the vast data more conveniently and effectively [12].</li> </ul>	<ul style="list-style-type: none"> <li>• MATLAB</li> <li>• Microsoft Azure</li> </ul>

Tools/ Explanations	Examples/ Explanations	Examples of Development Tools/ Platforms
<p><b>Communication tool</b> Using the online platform, making the connection easier. It is more convenient for lecturers and students to communicate if their devices are connected to the Internet. It can be used to eliminate communication barriers, such as space and time barriers.</p>	<ul style="list-style-type: none"> <li>• Private chatbox</li> <li>• Email</li> <li>• Social media</li> </ul>	<ul style="list-style-type: none"> <li>• Microsoft Team</li> <li>• Zoom</li> <li>• Google Classroom</li> </ul>

Integrating ICT technology brings many advantages to engineering education. However, some barriers affect the implementation, including insufficient adequate tools, data privacy concerns, and increased complexity of the teaching method [13].

In CAL practice, multimedia is most commonly defined as the use of at least two of these elements: sound (audio), text, still graphics, and motion graphics (visual) [37]. With the increasing influences of multimedia ICT

technology in education, the multimedia element like 3D-Animation, AR and VR expands the capabilities in bringing more interaction between information, learners, and educator. The conventional educational framework shows less interactivity between learner and educator. However, the use of Multimedia CAL Packages increases the engagement and connectivity between the learner and educator [10]. Selected multimedia CAL packages are listed in Table 2.

Table 2. Multimedia CAL packages developed for engineering education [10]

CAL Packages	Educational Objectives
Interactive Dynamics learning Course (IDLC) web-based simulations [38]	Simulations of different mechanisms studied in the IDLC will be made available to the students on the course website to supplement the course of the interactive dynamic in the classroom.
Visualisation tool using Sim2Bil [39]	This research study utilised the visualisation tool Sim2Bil, which combines a simulation of two cars, velocity graphs, and input for velocity functions to facilitate mathematics education in engineering studies.
Interactive Computer Simulation and Animation (CSA) module [40]	A new interactive CSA module was developed in an undergraduate engineering dynamics course to improve student learning of particle kinetics. This CSA module is unique in that it combines computer visualisation with mathematical modelling, allowing students to connect engineering dynamics phenomena to the underlying mathematics directly.
Technology-Assisted Problem Packages (TAPS) Tool [41]	Using Desktop Virtual Reality (DVR) approach to provide better simulation and visualisation of Mechanics Dynamics problem through 2-D and 3-D animation models.
Interactive Learning approach using interactive module and presentation software (Slidedog) [42]	This research introduced an interactive learning approach for teaching engineering design courses Structural Steel Design using an interactive module, video-recorded session, and presentation software "Slidedog." Each interactive module consists of pre-class brainstorming questions, a lecture on theory with related code specifications, tables and charts, practice problems and exercises arranged in a series of guided steps, and mini video clips.
Using Holograms for visualising and interacting with educational content in a Teaching Factory Setup [43]	This work utilises the holographic system to visualise complex 3D models in real-size dimensions, which provide 3D visualisation in Teaching Factory Setup.
Application of Multimedia Technology in Water Conservancy [44]	This research utilises the system simulation technology for water conservancy and hydropower projects. It helps to simulate hub layout, the structure of prominent buildings, dam flood discharge, rubber dam overflow, sluice dispatching process, ship lock crossing process.
Using Augmented Reality Framework and mobile device in Engineering Education (M- Learning) [45]	This paper proposes a framework for using Augmented Reality in mobile phones for engineering education and providing a new educational paradigm called M-Learning (Mobile-Learning).

## V. LEARNING APPROACHES

Learning approaches are essential in order to ensure the quality of engineering education. The rapid growth of ICT technology has brought multiple possibilities for learning approaches. There are commonly three types of learning approaches which are traditional classroom, online learning and blended learning.

### A. Traditional Classroom

A traditional classroom is a teacher-centred teaching method where teachers deliver knowledge or instruction in a physical classroom in a specific place and time. Students are given homework or assignment to complete after class hours. A traditional classroom is more towards passive

Learning as students need to follow the schedule already fixed by the teacher. Besides, the learning material is more in text form like textbooks, PowerPoint slides, traditional libraries [10].

### B. Online Learning

Online learning is a virtual classroom driven by ICT technology. ICT technology widens the possibilities of instructors to deliver their knowledge. MOOC (Massive open online course) is one example that adopts ICT technology to deliver knowledge. There are a few examples of MOOCs such as google classroom, Khan Academy, Coursera, etc. As the course material is provided on the Internet in digital multimedia, the student could easily acquire a large amount of related information

through a simple keyword search. This helps keep their pace in the latest developments [10].

### C. Blended Learning

Blended learning is a learning program where utilises more than one delivery mode to optimise the learning outcome and cost of program delivery. According to the literature review, the development of blended learning is to overcome the shortcomings of traditional learning and online learning by providing a combination of various teaching strategies or methods [46].

Blended learning integrates learning and comprehensively uses various learning-based activities, including face-to-face teaching, Internet or e-learning, student-centred learning, and self-paced learning [42], [47]. The flexible setting of the blended learning approach encourages lecturers to select a model or approach that best matches their pedagogical approach, the classroom and technology constraints [48].

A researcher mentioned blended learning is about integrating the “right” learning technology to match the “right” personal learning style to transfer the “right” skills to the “right” person at the “right” time in order to optimise learning outcome and the infinite range of possibilities [49]. The “right” terms in the sentence can be further elaborate as the appropriate blended learning setting. Additionally, in order to ensure the “right” ingredient of a blended program, there are few aspects that need to emphasise as following:

#### 1. Audience

Several factors are considered during audience analysis, including preferred learning style, basic knowledge, motivation, and accessibility. These factors must be considered when deciding on a blended learning model that will result in a successful learning outcome.

#### 2. Content

The characteristics and goal of the course will be the focus of content analysis. Some courses necessitate more face-to-face interaction, while others necessitate the use of simulation tools. It is recommended that complex physical skills be delivered in face-to-face formats.

#### 3. Financial

Financial analysis is required to determine the delivery option. The main financial benefit of self-paced content is that it is less expensive to deliver than real-time content. A highly interactive and media-rich self-paced training program, on the other hand, could cost thousands of dollars per hour of deliverables and take weeks to develop.

#### 4. Infrastructure

The delivery options may be limited due to infrastructure. Because some blended learning models promote small group discussion and different station rotations during the physical class, classroom capacity is often limited. Furthermore, mobile device's screen size and network access differ from those of personal computers, with enough network bandwidth to access high-quality motion video.

According to the research in K-12 education, blended learning in the curriculum brings vast advantages in terms

of quality and cost [50]. K-12 education is a Blended learning provides a more consistent and personalised pedagogy that allows students to learn at their own pace and using their preferred learning modes. Besides that, the ability to playback or revise the material gives the student have more resources to learn without trap in a fixed time and location. In addition, in terms of using time and space more efficiently, blended learning encourages the lecturer to utilise the ICT technology, which delivers some of the content online while utilising the physical classroom with more interacting activities, increasing students' motivation. In general, blended learning improves learning outcomes by better matching how learners want to learn and the course objective.

According to a Material Engineering study conducted in Malaysia, most universities in the country adopt blended-learning methods into their teaching and learning processes before the COVID-19 pandemic. Students discovered that visualising the structure of a material by imagination was a difficult capacity to master. As a result, they employ web-based visual tools to aid students in their visualisation. [51]. This example supports that Blended Learning provides lecturers with flexibility and diverse way to assist students in learning.

## VI. BLENDED LEARNING APPROACHES

Most blended learning approaches can be categorised into four models: rotation, flex, a` la carte (self-blend), and enriched virtual. The Rotation model includes four sub-models: station rotation, lab rotation, flipped classroom, and individual rotation [42]. Table 3 refers to the previous work from Staker and Horn, which explains how each blended learning approach worked. In this paper, the word “approach” is interchangeable with “model” used in the Staker and Horn study. This paper will focus on blended learning using flipped classroom approach.

Table 3. Types of Blended Learning Approaches [50]

Types (Model)	Explanations
<b>Rotational</b>	Given a course or subject, students can rotate between different learning modes according to a fixed schedule or a plan decided by teachers. At least one of the modes is online learning. Other learning modes may include activities, such as small group or whole-class instruction, group projects, personal tutoring, and pencil and paper assignment. The Rotation model includes four sub-models: Station Rotation, Lab Rotation, Flipped Classroom, and Individual Rotation.
<b>Station Rotation</b>	Students rotate in the classroom learning mode follow a fixed schedule or plan determined by teachers. The rotation includes at least one online learning station. Other stations may include activities such as group or class lectures, group projects, personal tutoring. Some implementations involve whole classes alternating among those activities, while others will divide the class into small groups loop one station after another. The station rotation model is different from the individual rotation model because students rotate through all stations, not only those schedules that have been customised.
<b>Lab Rotation</b>	Students rotate attending classes in different places of the physical campus according to a fixed schedule or follow the plan determined by teachers. One of these spaces is an online

Types (Model)	Explanations
	learning laboratory, while others classrooms will accommodate other learning methods. The lab rotation model is different from the station rotation model because students rotate in different places on the campus instead of studying blended courses or subjects in one classroom.
<b>Flipped Classroom</b>	<p>Students rotate between carrying out face-to-face teacher guidance and viewing the delivered content and instruction online from a remote location during physical class. Flipped classrooms differ from students who only do homework exercises online at night because most content and instruction are delivered online. The flipped classroom model empowers students to take charge of their learning:</p> <p>I. <i>Where they review the course material and instruction?</i> The students can review the material they are comfortable with as long as their devices are connected to the Internet.</p> <p>II. <i>When they review the course material and instruction?</i> Students can review the material anytime as long as they manage to complete the instruction before the class or before the deadline. They can at their own pace and flexible hour.</p>
<b>Individual Rotation</b>	Students rotate on their personally customised schedule or individualised playlist among the learning modes, one of which will be online learning. This individualised playlist does not have to rotate to each available station or learning mode, making it different from the station rotation model.
<b>Flex</b>	<p>Online learning is a pillar for a program or courses which adopt the flex model. The students rotate on a personally customised schedule or fluid schedule among the learning modes, and the teacher-of-record will provide the guidance.</p> <p>Although online learning is the primary element in the flex model, the teacher-of-record on-site will also provide face-face support through small-group instruction, group projects, and individual tutoring upon students' needs.</p>
<b>Self- Blend</b>	Self-Blend Model is when students take one or more courses online to enhance their traditional courses and online learning. There is no emphasis on whether the students must choose an online class or physical class. This differs from full-time online learning and the enriched-virtual model because it is not a whole-school experience. Students take the initiative to self-blend some online courses or traditional face-face classes at a brick-and-mortar campus.
<b>Enriched-Virtual</b>	It is a whole-school experience, wherein in each course, the students will divide their time in attending physical class in academic brick-and-mortar campus (physical class) and online learning. Full-time online schools often adopt the enriched-Virtual model; they develop the blended program to provide some physical school experience. Different from flipped classroom model, the Enriched- Virtual model's students seldom attend a physical class every weekday.

## VII. FLIPPED CLASSROOM APPROACH

The flipped classroom is one of the sub-models of rotation blended learning model. Blended learning focuses on blending online learning and face-to-face learning (traditional learning). Flipped classroom is a technology-

enhanced teaching technique in which students (a) get course materials before each class session via instructional videos, text-based materials, or online assignments (pre-class) and (b) participate in interactive learning activities inside the classroom (in-class). Students in a flipped learning environment can access pre-class learning materials at any time and have extra time in class to seek support from their teachers and peers [52].

Time consuming during lecturer class is always the main concern of the lecturer. Some lecturers argue that it is very challenging to provide a diversified teaching method and personalised learning experience to the student. It usually takes up valuable minutes that students and lecturers have to interact with each other and the materials [53]. Flipped classroom is a blended learning model which reverses traditional learning. It proposes where the teacher delivers the knowledge and extends how to interact outside the formal class by doing some class activities out of class, assigning pre- or post-class activities to benefit from in-class work, and using technology, especially video [42]. Research indicated that watch related online videos as a supporting tool could assist students in spending their learning time and significantly impact their learning. [54].

Students must gather at a classroom study together and more focused on passive learning in the traditional teaching method. Flipped classroom provides an alternative teaching method, which overcomes the limitations of the traditional teacher-centred teaching method through student-centred activities and interaction between learners and teachers. Through this method, the students will be exposed to different learning activities, such as whole-class brainstorming, group-based hands-on assignments, peer-review, feedback exchange, preview learning material, etc. As such, the teacher 'delivers' or "conducts" lectures before class in the form of pre-recorded videos and spends more class time engaging students in learning activities that involve more collaboration and interaction with students [55]. The learning process begins with reviewing the materials before class, communicating with teachers during face-to-face class, then applying the materials and knowledge after class on the Internet or in homework.

Moreover, research further adds that the flipped classroom concept is consistent with active learning, which encourages students to participate in teaching activities instead of passively or blindly listening and learning [56]. In general, the flipped classroom is not a new concept. It is a more enhanced blended learning model driven by technology, especially multimedia and ICT technologies which helping the lecturer to overcome the time burden and way to deliver the knowledge [57].

Flipped classroom invert the classroom in these aspects:

### 1. Role of lecturer and student:

The lecturer works as an instructor in the flipped classroom, which provides guidance and facilitation during class. Students are the main subject in the flipped classroom to control their learning pace using online recourses. They can learn according to their situation and comfortable atmosphere, which is a more relaxed learning pace.

**2. The conventional class in terms of class procedures:**

Traditionally, the students receive knowledge in the class and apply the knowledge after class through homework or assignments. The face-to-face class is more on interacting activities (discussion, project, etc.) by implementing flipped classrooms. Besides

that, in the traditional classroom, students often come with an “empty cup,” flipped classroom encourages students to come to class with a “half cup of water,” which they prepare and review the material before class.

Table 4. Case Studies of Flipped Classroom Used in Engineering Courses

Case Studies	Sample Size/ Findings
A control systems course in the Department of Mechanical Engineering at Seattle University, USA. [58]	Target for 20 senior mechanical engineering students. The findings of this study were positive. The flipped classroom concept allowed students to use class time to solve individual and group problems. Instructors could cover more material in the flipped classroom than in lecture class, but students performed equally well on quizzes and exams and scored higher on design problems, adapted to the format quickly, and expressed equal or greater satisfaction.
Engineering Mathematics classroom for sophomore year students at King Mongkut’s Institute of Technology Ladkrabang (KMUTT), Thailand [59]	Average class size 45 to 70 students. Overall, the course flipped was a success, as evidenced by student performance in in-class problem-solving sessions and individual opinion surveys and interviews. The ability for instructors to guide as students spend time preparing materials before coming to class provides the flexibility and potential to use class time in the most beneficial way for students.
Electric Drives course in the Electrical and Computer Engineering Department at the University of Minnesota [60]	From 2012- 2014, three groups totaling 250 students participate in this study. Students reflected that the flipped classroom’s innovative teaching method has helped them develop learning interests, shift their ideas about learning, and enhance their study habits. Research acknowledges that both students and instructors have a unique opportunity to achieve the crucial educational aim of optimising learning potentials while spotting gaps between students’ current learning and learning potential.
Introduction to Electronics course at a New Zealand University [61]	Sample size approximately 150 students. Students claim they prefer to learn from a live person (teachers, demonstrators, peers). Students are not fully engaging with the prescribed weekly videos, according to video analytics data. This suggests that the current strategy for motivating students to view videos and come to face-to-face class sessions prepared to participate in active learning tasks and ask questions may need to be revised.
Structural Steel Design, a course required for the Bachelor of Science in Architectural Engineering program [42]	Two groups of students, 95 students in traditional classroom while 97 in flipped classroom. The improvement of students’ skills reflected positively in their exam performance and course assessment. During group discussion, it was noted that students with higher exam scores viewed online lecture material more consistently than students with lower exam scores.
Flipped Classroom Technique in Improving Students’ Grade of Transport Phenomena Course in Universiti Teknologi PETRONAS (UTP) [62]	54 students from 3rd-year Chemical Engineering. The flipped classroom has been found to be helpful in terms of enhancing students’ grades and comprehension. Following the adoption of the flipped classroom, the number of students receiving an ‘A’ on each examination has increased. The students stated that adopting a flipped classroom allows them to learn more effectively.

Table 4 describes the implementation of flipped classrooms in engineering education and their findings. The case studies flipped classroom had several positive impacts in different engineering courses. However, most of the case studies were from other countries. There is still a lack of research regarding the implementation of the flipped classroom in Malaysia’s engineering education.

Flipped classroom have become common use in the higher education, especially during this COVID-19 pandemic where most of the classes are conducted online [46], [63], [64]. However, previous works suggest that future improvements of the quality of using flipped classrooms in more subjects strengthen students’ readiness in using flipped classrooms, especially in encouraging students to take responsibility for their learning progress [65]–[67]. Moreover, the research claimed that there does not seem to be an agreement on what flipped learning is and how effective it is in improving student learning [5]. Therefore, more research regarding the implementation of flipped classroom approach should be done to provide more action plans in developing and evaluating flipped classrooms in engineering education.

VIII. CONCLUSION

Teaching is a knowledge-delivering process that requires various techniques, strategies, and approaches that can significantly impact the students. Blended learning is a current trend of engineering education that can vary the combination of learning approaches primarily through ICT technology.

In general, this paper reviews that although blended learning using flipped classroom approach has a remarkable positive effect on the study cases, there is still room to improve and investigate this learning model. The implementation of the flipped classroom is getting more popular among tertiary education [68]. The learning effect they achieve through flipped classrooms is remarkable, including promote self-paced learning, increase the interactivity and collaboration between learners and instructors. However, some barriers need to be solved, especially in connecting issues, facilities, and devices issues. Despite this increasing interest in the flipped classroom, only a few cases focus on engineering education. This encourages further investigation of

blended learning using flipped classrooms in enhancing the quality of engineering education.

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