TEACHING PEDAGOGY FOR ENGINEERING EDUCATION

(Date received: 05.10.2022/Date accepted: 10.02.2023)

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ABSTRACT

In this paper, the teaching philosophies for electrical and electronics engineering education are presented. Being academics in the tertiary institutions emphasis should be placed in the education of knowledge, the constant enhancement of personal knowledge via life-long learning, and the expansion of existing knowledge. In order to mediate an effective teaching and learning process, the implementation of the principle of parsimony in educating the students should be advocated. Since everyone is unique in his/her own way, an educator should also treat the students impartially and sincerely. Different teaching approaches which were developed from the basis of these philosophies have been proposed. The approaches include keeping the explanations simple, predicting the questions and answers, ensuring that the teaching flow is managed in a gradual, systematic, and progressive manner, introducing metaphors, similes, and analogies to assist the pace of learning, using graphical and/or video illustrations, as well as, organizing site visits. The importance of cultivating interests among students should also be stressed. This can be achieved by constantly engaging with the students, keeping the atmosphere collegial, sharing personal real-life experience, incorporating fun activities in the classes, and encouraging students to transcend beyond the requirements set by the educators. It is also worthwhile noting that, the teaching approaches are to be periodically reviewed for continuous improvements.

Keywords: Education, Impartial and sincere education, Knowledge enhancement, Knowledge expansion, Principle of parsimony

1.0 INTRODUCTION

Teaching and learning are a duplex process. While conveying knowledge to the students, with or without an educator realizing it, he/she is learning from them as well. An educator can easily learn from the students how receptive they are with his/her teaching method by scrutinizing the students' behaviour and, sometimes, via their direct feedback. At times, a cosy teaching and learning environment is also conducive for knowledge sharing. Students tend to interact actively with the educators when the atmosphere is suffused with a sense of belonging. This does not only foster the teacher and learners' relationship; it also provides an avenue for knowledge transfer between both parties.

The generations are changing, and, in fact, they are evolving fast. Some of these changes are subtle, while some are conspicuous. Because of this reason, an educator must be particularly meticulous when observing the behaviour of the students (i.e., their gestures, facial expression, cognitive skill, etc.). To ensure an effective process for knowledge transfer, constant attempts to modify the teaching methods to synchronize with the pace of this evolution is necessary. Being able to cope and adapt to the capricious environment certainly, and most definitely, enhances the efficacy of knowledge discovery and propagation.

The study conducted by Choudhury (2019) suggested that a more interactive approach should be implemented to improve the quality of engineering education. In order to enhance the efficacy of knowledge assimilation in engineering education, Hernández-de-Menéndez *et al*. (2019) have proposed adopting a student-centered-learning approach, known as Active Learning. Similarly, Muradilloyevich *et al*. (2020), Nancy *et al*. (2020), Almetov *et al*. (2020), and Lanzo *et al*. (2020) advocate using innovative approaches, such as modelling programs, smart gadgets, and virtual environments to improve the teaching process. In 2014, Metropolia University of Applied Sciences reformed its curriculum into multidisciplinary courses implemented by teacher teams (Vesikivi *et al*., 2018). The purpose of doing so was to inculcate engineering graduates with the necessary skills. It can be seen from the literature that, the ultimate objective for implementing these different types of approaches is to enhance the effectiveness of education in the engineering discipline. The conveyance of knowledge in engineering education is clearly important because it helps to equip graduates with the necessary survival skill sets in workplaces (Yee and Ho, 2015).

This paper presents the philosophies that has been guiding the author throughout close to 18 years of his teaching career. The teaching methods which are developed based on these philosophies have been implemented to impart knowledge to the students in the engineering field.

2.0 TEACHING PHILOSOPHIES

An educator is perceived as a beacon to illuminate those who wish to learn – in particular, the younger generations. The obligation of teaching is not solely restricted to the task of knowledge transfer. It is a complicated and continuous process which also involves the assimilation of knowledge from different sources and the discovery of new knowledge for the improvement of the society and mankind. In a nutshell, the teaching philosophy proposed

here encompasses education (i.e., to educate the learners), enhancement (i.e., to enhance our own store of knowledge), and expansion (i.e., to expand existing knowledge).

It is also worthwhile noting that, knowledge transmission must also be based on the basis of simplicity. An educator who knows his field well should be able to express himself clearly using the simplest possible and most fundamental method of explanation. He or she should also teach sincerely and impartially.

2.1 The EEE Philosophy

As mentioned in the preceding section, the essence of teaching can be summarized using the EEE philosophy – in which, the three 'E's represent 'Education', 'Enhancement', and 'Expansion'.

Many may view education as a mere process of regurgitating knowledge from reading materials and passing it down to the students. When one delves further into this career, however, one may have the epiphany that it is far more than what it seems to be initially. Apart from the technical skills and knowledge that an educator possesses and wishes to convey, education also involves reaching out to the students and sharing with them the thoughts and behaviour, the beliefs that an educator holds firmly to, and the principles that govern an educator's life. These are the attributes which help to shape the personalities of the students. In other words, an educator's own personal conduct is equally important as the knowledge that he or she possesses. Very often, the teacher is the person whom the students look up to. To the students, their teachers are always their quintessence of virtue. Hence, it is imperative for the educators to constantly remind themselves to uphold and maintain academic and professional morality and integrity.

Educators should also be aware that the teaching and learning process is constantly vibrant. The world is not stagnant, neither is knowledge. Both are growing rapidly over time. To share bleeding edge information to the students, educators have to equip themselves from time to time with the latest know-how. This is especially true for educators involved in teaching courses related to engineering programmes, such as the electrical and electronic engineering. The electrical and electronic industries are developing in leaps and bounds. Today, we are in the cusp of the fourth industrial revolution (IR 4.0), where microchips are operating in the nanometers regime and signals are traveling at the submillimeter wavelengths – the telecommunication technology is now progressing towards its fifth generation (5G). It is the obligation of educators to ensure that the information that is disseminated to the students is contemporary, if not precocious. Hence, educators are required to develop their professional knowledge consistently and persistently in this field.

An educator should also play a part in contributing to the existing store of knowledge. As a researchers, as well as educators in a tertiary institutions, it is incumbent upon educators to seek for novel discoveries in science, technology, engineering, and mathematics (STEM). Excavating new knowledge and sharing it with the community help to expand the horizon of the society and propel the nation to stride forward.

All in all, an effective teaching process usually requires these three elements to be intertwined seamlessly. Educators have to consistently explore new knowledge – discovered either by themselves or others and educate the students with the knowledge that they possess.

2.2 The Principle of Parsimony

The principle of parsimony, or better known as the Ockham's razor (Sober, 1981), advocates one to seek the simplest explanation for a phenomenon (Lazar, 2010). This is to say that a phenomenon should be explained based on the least assumptions and using the simplest form and, yet the explanation is able to convincingly support the manifestations found. Although this principle is commonly implemented in scientific research, it is equally valid in the light of teaching and learning. An educator who is proficient enough in his/her own field should be able to find an easy-to-understand and appropriate method to explain to the students the subjects which are of intricate depth. One should resort to the method of explanation, which is simple but sufficiently accurate, so that even a novice could have the least difficulty in grasping the gist of the subjects. As a matter of fact, a good educator should avoid using terminologies that are so complicated that only aficionados could comprehend, since this will hamper the channel of knowledge propagation. This is especially true when the educator is teaching a group of students, with every one of them having different levels of knowledge absorbing capabilities.

2.3 Impartial and Sincere Education

There is no doubt that one must own various traits to become a successful educator. The febrile passion in teaching, possessing a magnetic personality, effective communication skill, empathy, etc, for instance, are probably some of these traits. However, to teach all students wholeheartedly and to treat every one of them equitably is certainly something an educator could not do without.

To be fair to the students does not mean that the educator has to sacrifice the same amount of time and effort for all students. Each student is unique in his/her own way. Hence, an educator must know how to optimize their strengths and improve their weaknesses. This is to say that each one of them who needs help deserves different amount of attention from the educators. Very often, educators may come across students who are slower in picking up certain subjects in comparison to others. Also, some students may find themselves struggling in adapting to a foreign environment; while others have little difficulty to do so. Hence, to be fair to all students is to ensure that all of them are able to cope well at the end of the day. Educators are supposed to provide tutelage to those who require the need, without discrimination and prejudice and of course, with patience and sincerity too.

3.0 STRATEGY IN TEACHING AND LEARNING

To put it in simple words, teaching and learning is nothing more than the mere process of transmitting and receiving information. To cultivate an effective teaching and learning environment, adopting the correct teaching approaches is of foremost importance. One may have to identify and learn a variety of teaching methods and apply them based on the necessary situations. The key objective of doing so is to ensure that majority, if not all, of the students are able to receive the information that an educator intends to convey. Different classes and different cohorts may exhibit different demographic characteristics. Hence, an approach which works well for a particular group of students may fail when applied to another group. This also means

that, educators should always stay vigilant when conducting their teaching duties. While teaching, educators also need to observe the students to assess their "absorption" rate. Choosing the right approach not only allows the students to learn effectively, it also instills certain tinge of motivation in the students.

3.1 Teaching Approaches

When teaching the students, a simple and direct approach is to be adopted. Keeping the explanation simple and straight forward is an art which may sometimes be challenging to master. When a theorem is inherently complex or an equation is mathematically involved, then one may have to spend quite some effort to gather a way to describe it in its simplest sense. It is essential for educators to make sure that the essence of the theorem or equation is unaltered when describing it using simple and fundamental language. To be able to do so usually requires a profound understanding of the subjects that the educators are teaching.

Educators also have to predict the questions that the students may ask and the answers that should be provided to them so as to convince them. When preparing for a class, educators should try to put themselves in the students' shoes. Very often, educators may wish to ask themselves, "What kinds of problems would we face if this subject is totally new to us?". The words used when describing the same subject may also differ, depending on the grades (i.e., either freshman, sophomore, junior or senior) and the academic results (i.e., the CGPA) of the students. Hence, it is advisable to gauge the students' level of understanding first before deciding on the exact word or method that is to be used for teaching them.

The teaching process should also be conducted in a gradual, systematic, and progressive manner. At times, an educator needs to be extremely patient when teaching the students – particularly, when some of them are slow learners. When there is a need, metaphors, similes and analogies can be used so as to assist the students' understanding. Take for example the electromagnetic fields and waves course offered virtually in all the electronic engineering programmes in any universities. Very often, the students face difficulty in visualizing the way waves propagate in transmission lines. As can be seen in Figure 1, when a pair of wires are connected to a voltage source at one end and a load at the other, electromagnetic waves travel between both ends. The propagating signal launched from the source is known as the incident wave and is denoted as V_0^+; whereas the signal ricocheted from the load back to the source is known as the reflected wave and is denoted as V_0^-. Maximum amount of power will only be transferred to the load when the reflected wave vanishes and the condition for this to occur is when the magnitude of the load (Z_L) matches that of the characteristic impedance (Z_0). For an experienced physicist or electrical and electronic engineer, this concept is perhaps reasonably logical to be understood; for a novice who has just begun to embark into the field of electrical or electronic engineering, however, it could be relatively abstruse. In order to assist the students in understanding the underlying principle, the author has drawn the image in Figure 2 and told the students to imagine that there are two dinosaurs, one at each end of the transmission lines. The dinosaur at the source is the mother and that at the load is her pampered child. Every time the mother (i.e., source) feeds her child (i.e., load) with muffins (i.e., V_0^+), she has to make sure that the size of the muffins (i.e., Z_0) is identical with the size of her child's mouth (Z_L); otherwise, a fraction of the muffins (V_0^-) will be spewed back to her. This analogy helps students to visualize the interaction of waves in transmission lines.

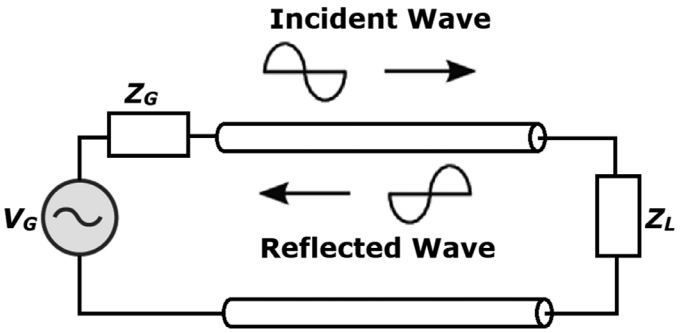


Figure 1: The circuit schematic of a source connected to a load via a coaxial cable (i.e. the transmission line)

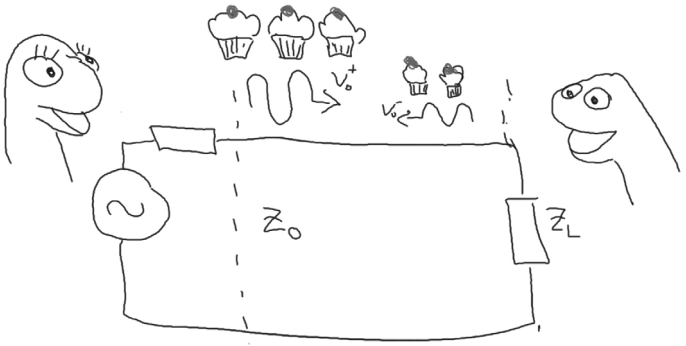


Figure 2: The author used analogy to teach transmission line theory

Figure 3: The students were asked to build solar cars from used aluminum cans for their assignments

Very often, graphical illustrations may become a helpful aid when educators are attempting to explain a subject which could sometimes be abstract to visualize (Yeap, 2020; Yeap *et al*., 2012). In electrical and electronic engineering, educators often come across subjects which are impalpable – such as, the flow of charges, the propagation of electromagnetic waves and the presence of electric and magnetic fields, to name a few. When it comes to situations where words alone have their limitation for elucidation, educators can resort to using graphics as a teaching aid. Most often than not, a picture is worth a thousand words. Hence, descriptions where words fail, images may come in handy. Graphics usually stay longer in one's memory than words. Therefore, drawings are also helpful in implanting knowledge and allowing it to stay firmly in the students'

memory. Of course, relying on drawings alone is insufficient. Showing actual real images or videos also help to accelerate the pace of understanding. Take for example, the fabrication process of a microchip. A microchip has to undergo multiple laborious stages before it could finally be taped out. In order to allow the students to appreciate the entire manufacturing process, videos published by chip manufacturers, such as Intel Corporation and Infineon Technologies can be employed for illustrations. This goes without saying that field trips would certainly be of great benefits to the students, since they could witness first-hand the actual manufacturing process which takes place in the factories.

Every now and then, educators should also engage themselves with the students. This is deemed necessary because many students are reticent to the educators. They will only open up to the educators when they start to sense the pastoral care that is extended to them. This helps to develop a sense of belonging in them. Interacting actively with them and using their jargons foster a bond of trust between the educators and the students. Doing so, educators would be able to discover the difficulties that the students face. The author saw changes in students who were initially recalcitrant. They gradually changed their attitude and became more amicable when they sensed the solicitude that is dedicated to them.

Another important aspect that educators have to consider when teaching, is the atmosphere of the class. A cosy and lively atmosphere helps to mediate an effective teaching and learning process too. One way to buoy up the atmosphere, is to tell jokes. Alternatively, educators can also initiate casual conversations with the students occasionally, to ensure that the atmosphere stays collegial.

Although it is delightful to see the students faring well in the subjects that the educators teach them, motivating them to embrace knowledge should preponderate. One should not study solely because one aims to attain good academic results. Such perspective diverts from the genuine objective of learning. Learning should be fun, and a student should learn because he/she is interested to do so. Hence, educators should also nurture the interests of their teachings towards the students. The sense of complacence will certainly imbue the educators when the students start badgering them for more information, with their eyes sparkling with excitement. Sometimes, an educator should also endeavours to give pep talks with words of encouragement. One may be surprised to find that enthusiasms and determinations that build up in the students can form a force to overcome the impediments that they face in the path of learning.

From time to time, educators can also attempt to introduce entertaining and fun activities into the subjects that they teach. Doing so, the students would be able to enjoy themselves while learning. The concept is similar to how parents encouraging toddlers to learn to walk. The skills will be naturally and eternally engraved into one's subconscious when one immersed in the fun process. Needless to say, the pace of learning will certainly be accelerated too. Take for instance the circuit theory course which, again, is a compulsory electronic engineering course in universities. The course describes the relationship of voltage and current and the theorems which govern them. In order to allow the students to relish the gist of the course, the author has asked the students to build solar cars from used aluminium cans, such as those depicted in Figure 3. The students are divided into teams and each team has to design and develop a workable prototype of its own. The farther and easier the car can manoeuvre, the higher scores the team will obtain. Of course, the ultimate aim of the assignment is to let the students learn how voltage and current generated from the solar panels could be determined. One other advantage of the assignment which is perhaps worthwhile mentioning here is that it inculcates environmental awareness and that the students learn about the importance of recycling wastes.

Cultivating creativity and innovation among the students should also be encouraged. The students should always aim to transcend the expectations set by the educators. Hence, the educators should motivate the students to deliver beyond the basic requirement that are set for them.

4.0 ASSESSMENTS ON TEACHING EFFICACY

Teaching and learning are a duplex activity. This is to say that educators are not supposed to deliver blindly without the initiative to evaluate the students' understanding. The efficacy of teaching could only be verified when educators are able to determine the students' level of understanding, and this could only be achieved via feedbacks from the students. Educators can gauge how receptive the students are to their teaching via interactions with them in the class (i.e., immediate measurements) and assessment of their coursework (i.e., overall measurements).

4.1 Immediate Measurements

Encouraging the students to involve actively in discussions allows educators to receive direct immediate feedbacks from them. Students who are active learners or who have devoted interests in certain subjects will normally volunteer themselves to share their views. An educator could easily tell from his/her discussion with the students how well they have learned the information that the educator intends to impart to them. Immediate corrective actions can then be taken by the educator once he/she is able to identify the students' problems on spot. Some of these corrective actions include giving more examples to the students or trying to use a simpler way to illustrate the same topic. Since a student's memory fades along with time, the problems that the students face may proliferate if clarifications were not provided promptly on spot. It is, however, worthwhile mentioning that not all students are often willing to share their problems. In every class, there is always a handful of which who are shy, quiet and, probably, introvert too. In order to ascertain how well these students in acquiring the knowledge that is delivered to them; educators may have to exploit indirect feedbacks. This can be accomplished via meticulous observation. Scrutinizing their facial expressions and gestures allows educators to gather hints of their level of understanding. Sometimes, educators can also pose questions especially to these groups of students, so as to assess them, and, of course, to also let them know that they have not been neglected.

4.2 Outcome-Based Education

The overall performances of the students are measured via the outcome-based education approach. This approach focuses on empirically measuring the students' performance with respect to a pre-determined set of outcomes (Soh *et al.,* 2010; Yeap *et al.,* 2014). The outcomes outline the attributes the students are expected to know upon the completion of the programme. This

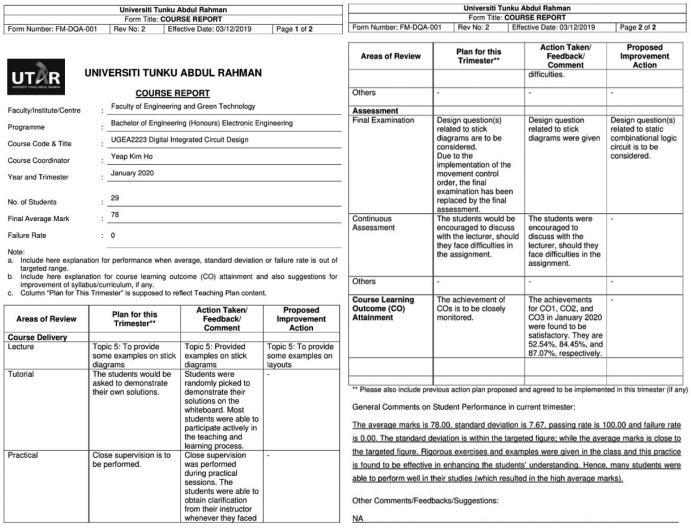
assessment method is currently widely implemented in literally all tertiary institutions in Malaysia. Hence, the coursework and examination questions are prepared in accordance with the outcomes put forth for the course (also known as the course learning outcomes); while these course outcomes are also aligned with the outcomes of the programme (also known as the programme learning outcomes).

There is no doubt that the educators should have certain form of impression on how well the students fare when they first go through the students' works. To be able to assess their works in a fair and systematic manner, however, it should be advisable to prepare rubrics for each coursework. By referring to the rubrics, educators could then grade the students' performance in a rigorous manner. Employing a clear and transparent method to assess the students' coursework is important because it helps the educators to pinpoint the obstacles that are clogging the channel of knowledge propagation – the common errors that most students tend to commit and the topics that many have difficulty grasping. Now, if these problems were identified and solved in time before the end of the semester where the students have to sit for their final examinations, then the educator could, at least, ensure that majority of the students are able to comprehend the essence of the courses, i.e., knowledge which corresponds with the course learning outcomes.

5.0 REVIEW OF TEACHING METHODS

One way to improve an educator's teaching skill is to periodically review both the teaching and assessment methods. It is useful to perform a full and thorough retrospect on the course that the educators have taught upon the completion of it. Since the author has been teaching engineering courses for years, there are some courses that he has been repeatedly teaching. Even so, he still discovers new insights in them every time he performs a thorough review on his delivery and evaluation methods. This is partly because our knowledge and experience grow over time; and partly, also because each individual tends to respond differently in the class. The conglomeration of these factors inspire revelation in us.

In Universiti Tunku Abdul Rahman, a course report is to be prepared at the end of every trimester. The course report records the review of the course. In other words, the educator is to analyze the teaching and assessment methods that he/she has implemented and develops plans for improvement, and all these are to be written down into the report. A course report for the digital integrated circuit designs course taught by the author in every January trimester is shown in Figure 4.



Universiti Tunku Abdul Rahman
Form Title: COURSE REPORT
Form Number: FM-DQA-001 | Rev No: 2 | Effective Date: 03/12/2019 | Page 1 of 2

UNIVERSITI TUNKU ABDUL RAHMAN

COURSE REPORT

Faculty/Institute/Centre : Faculty of Engineering and Green Technology
Programme : Bachelor of Engineering (Honours) Electronic Engineering
Course Code & Title : UGEA2223 Digital Integrated Circuit Design
Course Coordinator : Yeap Kim Ho
Year and Trimester : January 2020

No. of Students : 29
Final Average Mark : 78
Failure Rate : 0

Note:
a. Include here explanation for performance when average, standard deviation or failure rate is out of targeted range.
b. Include here explanation for course learning outcome (CO) attainment and also suggestions for improvement of syllabus/curriculum, if any.
c. Column "Plan for This Trimester" is supposed to reflect Teaching Plan content.

Areas of Review	Plan for this Trimester**	Action Taken/ Feedback/ Comment	Proposed Improvement Action
Course Delivery			
Lecture	Topic 5: To provide some examples on stick diagrams	Topic 5: Provided examples on stick diagrams	Topic 5: To provide some examples on layouts
Tutorial	The students would be asked to demonstrate their own solutions.	Students were randomly picked to demonstrate their solutions on the whiteboard. Most students were able to participate actively in the teaching and learning process.	-
Practical	Close supervision is to be performed.	Close supervision was performed during practical sessions. The students were able to obtain clarification from their instructor whenever they faced difficulties.	-
Others	-	-	-
Assessment			
Final Examination	Design question(s) related to stick diagrams are to be considered. Due to the implementation of the movement control order, the final examination has been replaced by the final assessment.	Design question related to stick diagrams were given	Design question(s) related to static combinational logic circuit is to be considered.
Continuous Assessment	The students would be encouraged to discuss with the lecturer, should they face difficulties in the assignment.	The students were encouraged to discuss with the lecturer, should they face difficulties in the assignment.	-
Others	-	-	-
Course Learning Outcome (CO) Attainment	The achievement of COs is to be closely monitored.	The achievements for CO1, CO2, and CO3 in January 2020 were found to be satisfactory. They are 52.54%, 84.45%, and 87.07%, respectively.	-

** Please also include previous action plan proposed and agreed to be implemented in this trimester (if any)

General Comments on Student Performance in current trimester:

The average marks is 78.00, standard deviation is 7.67, passing rate is 100.00 and failure rate is 0.00. The standard deviation is within the targeted figure; while the average marks is close to the targeted figure. Rigorous exercises and examples were given in the class and this practice is found to be effective in enhancing the students' understanding. Hence, many students were able to perform well in their studies (which resulted in the high average marks).

Other Comments/Feedbacks/Suggestions:

NA

Figure 4: A sample of the course report

6.0 CONCLUSIONS

In this paper, the author shares the teaching pedagogy that he has developed and clinging to throughout his career in the engineering education. In essence, the author believes that an educator should put emphasis in educating the students, constantly expanding his/her own store of knowledge, and discovering new knowledge for the benefits of mankind. When conveying knowledge to the students, an educator should resort to simple words and a straightforward mean of illustration. Since each student is special in his/her own unique way, an educator should also treat the students equitably and with utmost sincerity. The teaching pedagogy proposed by the author has been incorporated into his teaching methods. These methods have been periodically reviewed to ensure that knowledge could be propagated effectively. ■

LIST OF NOTATIONS

EEE is education, enhancement, and expansion
IR4.0 is the fourth industrial revolution
STEM is science, technology, engineering, and mathematics
5G is the fifth generation
V_0^+ is the incident wave
V_0^- is the reflected wave
Z_0 is the characteristic impedance
Z_L is the load impedance

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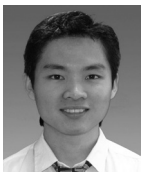
PROFILES



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