INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH in PROGRESSIVE EDUCATION & DEVELOPMENT

OPEN ACCESS JOURNAL

Vol 12, Issue 3, (2023) E-ISSN: 2226-6348

Power Electronics: Enhancing Understanding and Design Skills

Yusrina Yusof[1], Arni Munira Markom[1], Noor Hasliza Abdul Rahman[2]

[1]School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, MALAYSIA, [2]School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA, Cawangan Johor, Kampus Pasir Gudang, 81750 Masai, Johor, MALAYSIA

Corresponding Author Email: yusrin262@uitm.edu.my/arnimunira@uitm.edu.my

To Link this Article: http://dx.doi.org/10.6007/IJARPED/v12-i3/17277 DOI:10.6007/IJARPED/v12-i3/17277

Published Online: 16 September 2023

Abstract

This paper presents an analysis of the course design and its alignment with the course learning outcomes in the field of power electronics at School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA, Shah Alam, Malaysia. The study focuses on the content, teaching strategies, and assessments employed in the course and examines their effectiveness in facilitating student learning and achievement. The course design encompasses three main learning outcomes: analyzing power switching devices, examining power electronics converters, and designing power electronic converters. The content includes topics such as power semiconductor devices, rectifiers, voltage controllers, DC choppers, and inverters. Blended learning, lectures, and tutorials are the primary teaching strategies utilized, while assessments comprise tests, assignments, and surveys. The analysis of entrance and exit surveys demonstrates significant improvements in students' performance and confidence. The results indicate that the teaching strategies effectively fostered knowledge acquisition and competency development. Additionally, the course aligns with the Ministry of Higher Education learning outcomes, addressing cognitive skills, numeracy skills, and critical thinking and problem-solving abilities. The findings highlight the successful implementation of the course design and teaching strategies, emphasizing their impact on student learning and skill development in power electronics. This study contributes to the continuous enhancement of power electronics education and provides valuable insights for educators in designing and delivering effective courses in the field.

Keywords: Power Electronics, Course Design, Learning Outcomes, Teaching Strategies.

Introduction

Power Electronics is a rapidly advancing field that plays a crucial role in various applications, including renewable energy systems, electric vehicles, industrial automation, and consumer electronics (Rashid, 2014). It involves the conversion and control of electrical power using solid-state devices and circuits. As power electronic technologies continue to evolve, it becomes imperative for students to develop a solid understanding of power switching devices' characteristics, power electronic converters' operating principles, and the ability to design converters to meet specific specifications and requirements.

However, most students often find Power Electronics to be a challenging subject due to its mathematical and analytical complexity. The subject requires a strong foundation in mathematics, circuit theory, and control systems, as students encounter complex equations, nonlinear systems, and intricate mathematical models. Moreover, Power Electronics deals with abstract concepts and theories that may be difficult to visualize or relate to real-world applications initially. Understanding fundamental concepts such as power semiconductor devices' characteristics, switching waveforms, and control strategies can be challenging without practical examples or hands-on experiences. Additionally, the interdisciplinary nature of Power Electronics, incorporating concepts from electrical engineering, electronics, control systems, and semiconductor physics, further adds to the complexity. Students often struggle to establish connections and understand the subject holistically.

Despite the challenges it presents, Power Electronics is an indispensable subject for students pursuing electrical engineering fields. Its significance can be attributed to several factors. Firstly, Power Electronics finds widespread practical applications in modern technologies and industries, serving as the backbone for renewable energy systems, electric vehicles, motor drives, power supplies, and consumer electronics (Mohan et al., 2015). Through the study of Power Electronics, students acquire the necessary knowledge and skills to design, analyze, and troubleshoot these systems, contributing to the development of sustainable and efficient technologies. Secondly, there is a high demand for professionals with expertise in Power Electronics due to its diverse applications across industries such as power systems, renewable energy, electric vehicle technology, industrial automation, and semiconductors (Hart, 2011). Mastery of this subject expands students' career prospects and opens doors to exciting and impactful paths.

Additionally, Power Electronics plays a crucial role in system integration by effectively integrating different energy sources, like solar panels, batteries, and grid systems, and managing power flow in complex systems (Li & Lai, 2018). This skill becomes increasingly valuable in the context of evolving smart grids, microgrids, and distributed energy systems. Furthermore, Power Electronics empowers students with the ability to design efficient and customized power converters that meet specific requirements (Erickson & Maksimovic, 2021). This skill is vital for engineers engaged in the design and development of power electronic systems. By understanding the principles of power semiconductor devices, circuit topologies, and control strategies, students can optimize system performance, considering factors such as efficiency, size, cost, and reliability.

Lastly, Power Electronics is a dynamic field with ongoing research and technological advancements (Middlebrook & Cuk, 2021). By studying this subject, students engage with the latest developments in power semiconductor devices, converter topologies, and control techniques. This knowledge equips them to contribute to future innovations, research projects, and the advancement of Power Electronics as a discipline. Overcoming the challenges associated with Power Electronics enables students to acquire valuable skills, pursue rewarding careers, and contribute to the advancement of sustainable and efficient technologies.

In the field of power electronics, there has been a growing interest in exploring various approaches to education, including Open Distance Learning (ODL). However, it is essential to consider different instructional methods to cater to the diverse needs of students. While the studies mentioned (Markom et al., 2021; Ilham et al., 2021; Abdul Rahman et al., 2022) focused on ODL concepts in courses such as Introduction to C Programming and Introduction to Electric Circuit, our approach in this paper emphasizes face-to-face instruction.

The power electronics course discussed in this paper adopts a traditional face-to-face teaching approach, allowing for direct interaction between students and instructors. Although ODL approaches have their advantages, face-to-face instruction offers unique benefits in the field of power electronics. The hands-on nature of power electronics requires students to engage with physical components and laboratory equipment, which is better facilitated in a face-to-face environment.

By emphasizing face-to-face instruction, our power electronics course aims to provide students with practical hands-on experience and foster deeper understanding of the subject matter. This approach allows for immediate feedback, real-time problem-solving, and collaborative learning opportunities, all of which are crucial for mastering the complexities of power electronics.

Alignment of Course Design with Learning Outcomes

This course is designed for Bachelor of Engineering (Hons) Electrical Engineering at Universiti Teknologi MARA (UiTM), Shah Alam, Selangor, Malaysia. There are six chapters to be covered throughout 14 weeks as shown in Figure 1.

Figure 1: Course Content of Power Electronics

The course design aims to achieve three learning outcomes: (1) Analyzing the characteristics of power switching devices and comprehending the operating principles of power electronic converters: The course "Introduction to Power Electronics and Power Semiconductor Devices" provides a foundation for understanding the behavior and limitations of power semiconductor devices, including diodes, transistors (BJTs, MOSFETs, and IGBTs), and thyristors. By analyzing their current-voltage characteristics, switching behavior, and gate drive requirements, students gain insights into the operating principles of power electronic converters. This outcome equips them with the knowledge and skills necessary to design, analyze, and troubleshoot these systems, making valuable contributions to the development of sustainable and efficient technologies.

(2) Examining different quantities of power electronics converters through circuit analysis: Through the study of "Single-phase and Three-phase Uncontrolled and Controlled

Rectifiers," students gain a comprehensive understanding of rectifier operation, current commutation, voltage and current waveforms, and DC/AC analyses. By applying circuit analysis techniques, they can examine crucial quantities such as average and RMS voltage/current, ripple factor, rectification ratio or efficiency, power factor, and total harmonic distortion. This outcome enables students to assess the behavior and performance of power electronics converters, providing insights into system efficiency, power quality, and harmonic distortion.

(3) Designing power electronic converters that fulfill specific specifications and requirements: By delving into the topics of "Single-phase AC Voltage Controllers," "DC Choppers," and "Single-phase and Three-phase Inverters," students acquire the necessary knowledge to design power electronic converters. These topics cover the principles of operation, analysis, and control techniques. Students learn to consider factors such as voltage/current regulation, efficiency, power factor, total harmonic distortion, and component sizing. Mastering this outcome empowers students to design efficient and customized power converters that fulfill specific specifications and requirements. Such skills are vital for engineers involved in various industries, including renewable energy, power systems, electric vehicles, and industrial automation.

By achieving these learning outcomes, students develop a strong foundation in Power Electronics. They gain the necessary knowledge and skills to analyze power switching devices, understand converter operating principles, examine converter quantities using circuit analysis, and design converters to meet specific specifications. These outcomes are integral to preparing students for careers in fields where power electronic systems play a pivotal role in driving sustainable and efficient technologies.

Teaching Strategies

In the field of power electronics, various teaching strategies are employed to enhance students' learning experience and facilitate their understanding of complex concepts. Three commonly used strategies are blended learning, lectures, and tutorials.

Blended Learning: Blended learning is a teaching approach that combines traditional face-to-face instruction with online learning components (Chavan & Jain, 2016; Vaughan, 2014). In the context of power electronics, blended learning can be effectively utilized to provide students with a well-rounded educational experience. This approach may involve a combination of in-person lectures, hands-on laboratory sessions, online resources, virtual simulations, and collaborative activities. Blended learning allows students to engage with the course content in different ways, catering to various learning styles. It promotes active participation, self-paced learning, and the opportunity to revisit materials for deeper comprehension. By incorporating both online and offline elements, blended learning encourages students to take responsibility for their learning and promotes a more interactive and dynamic learning environment.

Lectures: Lectures are a traditional teaching method widely used in power electronics courses. During lectures, lecturers deliver structured presentations on key theoretical concepts, principles, and applications (Dhande & Patel 2019; Parmananda, 2017). Lectures provide an opportunity for lecturers to explain complex topics, provide real-world examples, and highlight important connections between different concepts. Through lectures, students can acquire foundational knowledge, develop a conceptual framework, and gain an understanding of the fundamental principles of power electronics. Effective lectures incorporate visual aids, demonstrations, and interactive elements to keep students engaged and facilitate their comprehension. To enhance the effectiveness of lectures, lecturers may also incorporate opportunities for student participation, questions, and discussions.

Tutorials: Tutorials are interactive sessions that provide students with the opportunity to reinforce their understanding of course materials through practice, problem-solving, and discussion (Rana & Babic, 2018 & Pellegrino 2020). In the context of power electronics, tutorials often involve working on problem sets, analyzing circuit diagrams, conducting simulations, and solving design challenges. Tutorials enable students to apply theoretical knowledge to practical scenarios, develop problem-solving skills, and clarify any confusion they may have. In addition, tutorials promote collaborative learning as students can engage in group discussions, share insights, and learn from each other's perspectives. Tutorials also provide a platform for lecturers to provide personalized feedback, address common misconceptions, and guide students through challenging topics.

Methodology

A. Sample and Instrument

A group of 27 students enrolled in the sixth semester of the Bachelor of Engineering (Hons) Electrical Engineering program at the School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA, located in Shah Alam, Selangor, Malaysia, participated in this study during the academic calendar from October 2022 to February 2023. Among the participants, 40 students belonged to the EE2425R1 and EE242P5B groups, specializing in power engineering, but only 27 of them completed both of the entrance and exit survey. To assess the course outcome of EPO 510, an "Entrance & Exit Survey" instrument was utilized, where participants were asked to rate their agreement on a scale of 1 (disagree) to 5 (totally agree).

B. Research Procedures

During the initial week of the course, students were introduced to the lesson plan, which included information about assessments, required materials, and the designated platform for the course, involving face-to-face interactions. To gauge their initial understanding of the subject, an "Entrance Survey" was administered during this period. The assessment structure consists of two tests: Test 1 covering chapters 1 and 2, and Test 2 encompassing chapters 4 and 5. In addition, an assignment is assigned on chapters 3 (during the early semester) and chapter 6 (towards the end of the semester). These assessments collectively account for 40% of the final grade, while the remaining 60% is allocated to the Final Exam, which evaluates knowledge across all chapters. To capture student feedback throughout the course, an exit survey was administered during week 14.

Results and Analysis

The results are based on the analysis of the collected survey data. Both the entry and exit surveys consisted of three identical statements, requiring students to evaluate their knowledge and skills performance in the subject. Statement 1 corresponds to the course learning outcome 1, as depicted in Figure 2: "I can identify the characteristics and drive requirements of power switching devices in power electronic applications."

In the entrance results (represented by the blue bar), most students rated themselves at scale 1-3, indicating limited or no knowledge in identifying the characteristics and drive requirements of power switching devices in power electronic applications during the early semester. However, at the end of the semester, after attending lectures and tutorials, the majority of students rated themselves at scale 4 and 5, demonstrating an improved understanding of power switching devices. The orange bar represents the exit results.

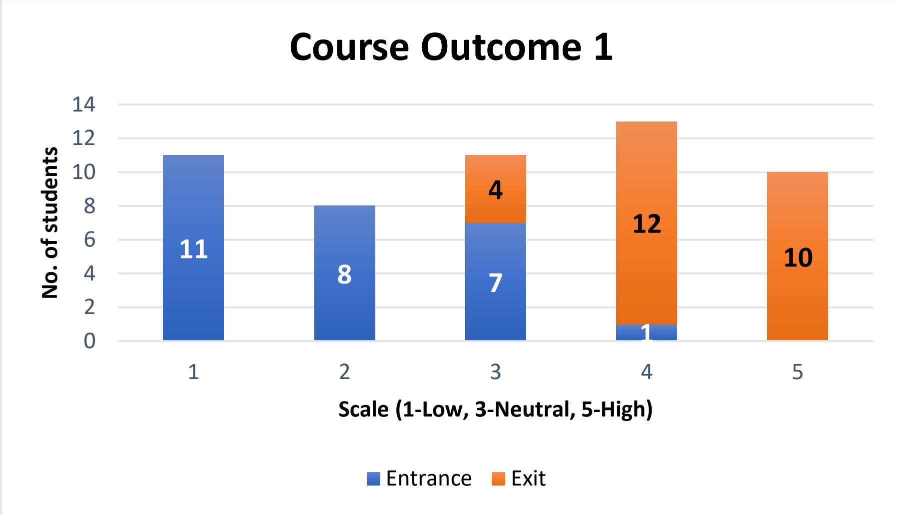

Figure 2: Entrance and Exit Survey Analysis for Course Learning Outcome 1

The second statement, based on course learning outcome 2 as shown in Figure 3, is "I can simulate various converter circuit topologies and control strategies." Similar to the first statement, the initial self-evaluation of students regarding their ability to simulate power electronics was predominantly at scale 1 and 2, indicating a lack of confidence and knowledge in this area. However, by the end of the semester, there was a notable increase in confidence and knowledge, as reflected by the higher ratings of scale 4 and 5.

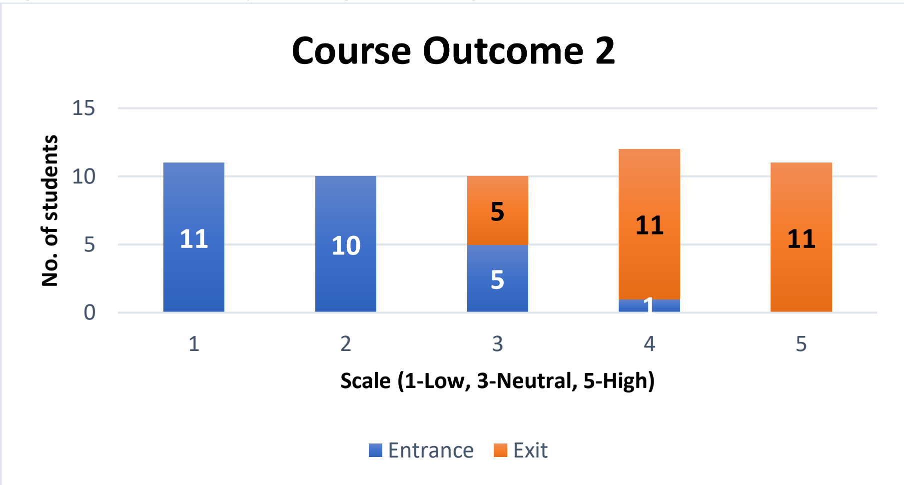

Figure 3: Entrance and Exit Survey Analysis for Course Learning Outcome 2

Finally, the last statement is based on the third learning outcome as shown in Figure 4, which is "I can evaluate the operation of power electronic converter circuits." As expected, the initial self-evaluation of students indicated a low level of understanding and familiarity with evaluating the operation of power electronics, reflected by their ratings at a lower scale. However, by the end of the semester, their confidence and knowledge had improved significantly, as evidenced by the higher ratings of scale 4 and 5.

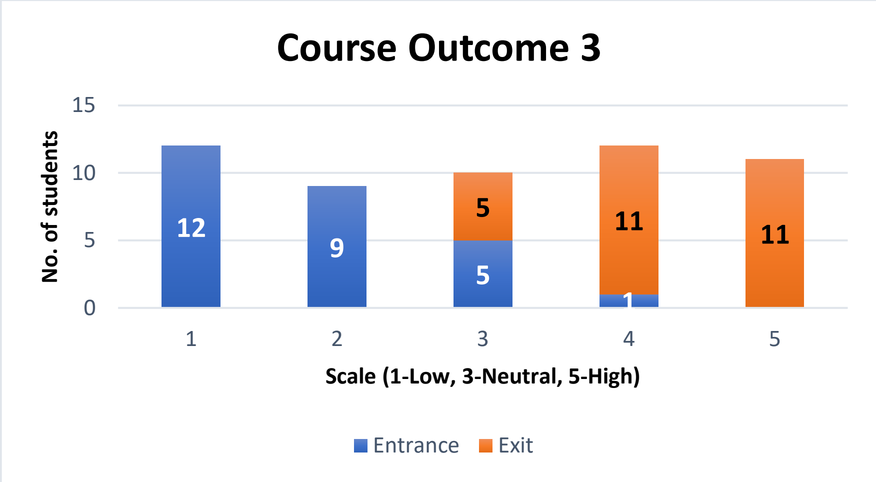

Figure 4: Entrance and Exit Survey Analysis for Course Learning Outcome 3

Table 1 presents a summary of the performance in the course learning outcomes. The average results for the entrance survey are below 2, while the average results for the exit survey exceed 4 for all three course outcomes. The percentage increase from the entrance survey to the exit survey for each course learning outcome ranged from approximately 46.67% to 48.15%.

Table 1
Summary of the Course Learning Outcomes

Course Outcome (CO)	CO1	CO2	CO3
Average Entrance Survey	1.93	1.85	1.81
Average Exit Survey	4.26	4.22	4.22
Increment Understanding (%)	46.67	47.41	48.15

Discussion

This study provides a comprehensive analysis of the course design and its alignment with the course learning outcomes in the field of power electronics. It demonstrates the effective integration of content, teaching strategies, and assessments to facilitate student learning and achievement of the desired outcomes.

The course design encompasses three main learning outcomes: analyzing the characteristics of power switching devices and understanding the operating principles of power electronic converters, examining various quantities of power electronics converters through circuit analysis, and designing power electronic converters to meet specific specifications and requirements. The content of the course, including power semiconductor devices, rectifiers, voltage controllers, DC choppers, and inverters, directly supports these learning outcomes and equips students with the necessary knowledge and skills.

The employed teaching strategies, such as blended learning, lectures, and tutorials, have proven to be effective in engaging students and promoting active learning. The combination of face-to-face interactions and online platforms has provided a well-rounded learning experience, allowing students to grasp complex concepts and apply them in practical scenarios. The assessments, including tests and assignments, have accurately evaluated students' understanding and provided opportunities for them to demonstrate their knowledge and skills.

Based on the analysis figures, all three learning outcomes exhibit similar patterns. In terms of the initial self-evaluations, only one student rated themselves at scale 4 during the early semester for these outcomes. This student was a repeat student who already had prior knowledge of the course content. However, it is noteworthy that at the end of the semester, a few students rated themselves at scale 3, indicating a moderate performance level. This suggests that these students possessed the necessary knowledge but may have lacked full confidence in demonstrating high levels of competency.

The findings suggest that the teaching methods and learning activities employed in the course were effective in enhancing students' knowledge and skills. The combination of blended learning, lectures, and tutorials provided a comprehensive learning experience, allowing students to grasp the essential concepts and apply them to practical situations. The results also highlight the importance of continuous assessment and feedback throughout the semester. By assessing students' knowledge and skills at both the entrance and exit surveys, it was possible to track their progress and identify areas of improvement.

The significant percentage increase in performance from the entrance survey to the exit survey indicates the effectiveness of the teaching strategies employed in the course. This is also achieving the Ministry of Higher Education (MOHE) learning outcomes for this course where outcome 1 targets cognitive skills, while outcomes 2 and 3 focus on numeracy skills. Additionally, the course has successfully imparted critical thinking and problem-solving skills, which are crucial in preparing students for real-world challenges.

These soft skills play a vital role in the professional development of students, enabling them to analyze complex problems, propose innovative solutions, and make informed decisions. Power electronics is a field that demands critical thinking and problem-solving abilities due to the intricate nature of circuit design and control strategies. By integrating these soft skills with the technical knowledge acquired throughout the course, students are better equipped to address real-world challenges in the field of power electronics. The ability to think critically and solve problems effectively enhances their employability and prepares them for successful careers in industries such as renewable energy, power systems, and industrial automation.

Conclusion

In conclusion, the analysis of the entrance and exit surveys revealed significant improvements in students' performance and confidence throughout the course. The results indicated a substantial increase in knowledge and competency, as reflected by higher ratings in the exit survey compared to the entrance survey. This signifies the effectiveness of the teaching strategies and the successful attainment of the course learning outcomes.

Moreover, the course aligns with the Ministry of Higher Education (MOHE) learning outcomes, addressing cognitive skills, numeracy skills, and fostering critical thinking and problem-solving abilities. These skills are crucial for students in the power electronics field, as they prepare to tackle real-world challenges and contribute to the advancement of the industry.

Overall, this manuscript highlights the successful implementation of the course design and teaching strategies, resulting in positive learning outcomes and student development. The findings provide valuable insights for educators in the field of power electronics and contribute to the ongoing improvement of power electronics education. By equipping students with the necessary knowledge, skills, and soft skills, this course prepares them for successful careers and positions them as valuable contributors to the field.

References

Chavan, A., & Jain, N. (2016). A Blended Learning Framework for Engineering Education: A Case Study in Power Electronics Course. International Journal of Engineering Education, 32(2A), 869-875.

Dhande, S., & Patel, K. (2019). Enhancing Learning Outcome of Power Electronics Course through Interactive Lectures. In 2019 IEEE 9th International Conference on Advanced Computing (ICoAC) (pp. 98-102). IEEE.

Erickson, R. W., & Maksimovic, D. (2021). Fundamentals of Power Electronics (3rd ed.). Springer.

Hart, D. W. (2011). Power electronics. McGraw-Hill Education.

Ilham, N. I., Markom, A. M., & Ibrahim, W. S. W. (2021). Students' Perceptions of Online Learning During Pandemic Outbreak: A Case Study of Electrical Engineering Students.

Li, X., & Lai, J. S. (2018). Power Electronics for Renewable and Distributed Energy Systems: A Sourcebook of Topologies, Control, and Integration. Wiley.

Markom, A. M., Yusof, Y., & Sadimin, S. (2021). Early Stage of Observation of Open Distance Learning Concept for Introduction to C Programming Course in Malaysia. International Journal of Academic Research in Business and Social Sciences, 11(10), 134-143.

Middlebrook, R. D., & Cuk, S. (2021). High-Frequency Switching Power Converters: Theory, Design, and Applications (2nd ed.). Wiley.

Mohan, N., Undeland, T. M., & Robbins, W. P. (2015). Power electronics: converters, applications, and design. John Wiley & Sons.

Parmananda, P. (2017). Enhancing Student Learning through Active Lecture Engagement. IEEE Transactions on Education, 60(3), 181-188.

Rana, S., & Babic, D. (2018). Flipping the Classroom in Power Electronics Education: The Role of Tutorials. In 2018 IEEE Frontiers in Education Conference (FIE) (pp. 1-7). IEEE.

Rashid, M. H. (2014). Power electronics: circuits, devices, and applications. Pearson Education.

Vaughan, N. D. (2014). Flipping the Blended Classroom: Making the Most of Blended Learning. IEEE Transactions on Education, 57(4), 222-229.