International Journal of Advanced Research in Education and Society
e-ISSN: 2682-8138 | Vol. 8, No. 2, 434-444, 2026
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Surveying the Impact of Innovative Practices of "EduVPC:i-Learn" among Thermodynamics Students

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Received: 10 January 2026 | Accepted: 25 March 2026 | Published: 1 April 2026

DOI: https://doi.org/10.55057/ijares.2026.8.2.34

Abstract: *Thermodynamics students often face challenges in understanding and mastering the calculations for the topic of the vapor power cycle. To address this issue, an innovative self-learning material, named EduVPC: i-Learn, was developed. This study aims to determine the potential impacts of using the innovative material of EduVPC: i-Learn by thermodynamics students on vapor power cycle achievement. The study involved two groups of respondents. The experimental group consisted of students who studied vapor power cycles with the support of innovative materials. In contrast, the control group comprised students who received standard lessons only, without any support of innovative materials. A series of demonstrations and activities was designed and delivered to the experimental group during the weekly lesson sessions. A self-assessment consisting of items related to the vapor power cycle was administered to both groups of respondents twice: as a pre-test at the beginning of the learning process or before the treatment process, and as a post-test at the end of the instruction, or after the treatment process. The analyses used in this study were the descriptive statistics, a one-sample t-test, and an independent-samples t-test. The study yielded very encouraging results, indicating that this innovative material can significantly enhance students' learning and achievement in vapor power cycle topics. The students in the experimental group showed substantially higher vapor power cycle improvement than the students from the control group. The experimental group also showed higher mean scores and high N-gain classification in the self-assessment conducted. This survey may have provided helpful information for course lecturers to encourage thermodynamics students to learn about vapor power cycles using this innovative material.*

Keywords: independent learning, innovative material, thermodynamics, vapor power cycle

1. Introduction

Thermodynamics is a core subject in the Diploma in Mechanical Engineering programme at Polytechnics Malaysia. Among its topics, the vapor power cycle in Topic 4 requires students to apply the Second Law of Thermodynamics as well as concepts and calculations from earlier topics such as steam properties and steady-flow processes. However, mastering this topic is often challenging for students because the analysis of the Carnot and Rankine cycles involves complex, multi-step calculations, as O'Connell (2019) noted that "Solving thermodynamics problems is often complicated." In addition, this difficulty aligns with the findings of Normah Mulop et al. (2012), Arwizet Karudin et al. (2024) and Khelloufi et al. (2025) that engineering students really face global challenges in learning the thermodynamics subject. Many students struggle to solve these higher-order cognitive questions - including analysis, evaluation, and problem-solving in thermodynamics (Wahidiyah et al., 2025; Saefullah et al., 2020). Besides, they also depend on lecturers to verify their solutions which reduces opportunities for independent learning and slows the students' learning process as well. In fact, according to Forbes-McKay et al. (2025), independent learning shows significant benefits to students which motivates them to learn and improve their academic achievement.

To address these issues, an Excel-based self-learning material, *EduVPC: i-Learn* (The Vapor Power Cycle Self-Learning Kit – For Students), was developed. The Excel tool is designed to help students learn and practice calculations, verify calculation results immediately, and boost their understanding of the vapor power cycle during independent learning. Through this innovation, it is expected that students will improve their mastery of thermodynamics—particularly the vapor power cycle—while fostering greater self-learning and enhancing their academic achievement. Therefore, the primary objective of this study is to evaluate the potential impact of using *EduVPC: i-Learn* on students' understanding and performance in the vapor power cycle.

2. Literature Review

Numerous prior works identify how innovative materials developed in thermodynamics can improve the students' learning process and academic performance. However, the authors summarized only some of these points here.

Arwizet Karudin et al. (2024) developed a data-based visualization tool using the Python programming language and the web-based Streamlit framework, hoping that this tool can assist students facing the challenges in their learning of the subject of thermodynamics. The tool integrates data from a mini steam power plant trainer and offers features such as automated data reporting, the heatmaps' correlation, the energy flow through Sankey diagrams, and the machine learning models to predict electrical output. Evaluation by thermodynamics experts rated the tool positively: information accuracy (4/5), visualization (4.25/5), educational value (3.75/5), and ease of use (4.5/5). These results support the statement that this tool is really effective in enhancing students' understanding of thermodynamics concepts by making data patterns, cause–effect relationships, and parameter changes. The study concludes that such visualization tools support self-directed learning, deeper comprehension, and alignment with modern data-driven educational approaches.

Fiandini et al. (2024) conducted an experimental study among the vocational students regarding the most effective method in teaching and learning process for the steam engines as electricity generators within the Merdeka curriculum. The study used was a pre-test–post-test experimental design, which compared the experiential learning with video tutorials (experimental group) against conventional teaching (control group). Statistical analyses (N-Gain and paired t-test) showed that the students from the experimental group improved significantly higher than the control group. The findings stress that experimental demonstration supported by videos is a more effective way than traditional teaching, as it improves comprehension, focus, and curiosity. Therefore, this study highlights that the teaching and learning process through experimental demonstrations among vocational students provides a more interactive and contextual way of learning experience for them.

Domínguez et al. (2023) developed a MATLAB application using MATLAB$^{®}$ App Designer, especially for teaching the Applied Thermodynamics course for chemical engineering students, where this application focused on teaching steam and gas power cycles and vapor-compression refrigeration cycles. This application generated case-based problems with random variables, displayed thermodynamics diagrams, and allowed students to export data and check solutions in Excel. Student surveys revealed that while some found the applications not straightforward to use, about 70% considered them an improvement in teaching and 75% wanted similar tools in other courses. Meanwhile, the responses from teaching staff were also encouraging too. The academic results showed a 15% increase in the pass rate after the implementation of this application in the teaching and learning process. Thus, it could be concluded that MATLAB-based applications can promote self-learning, improve understanding of thermodynamics cycles, and enhance course outcomes.

Sari et al. (2023) had implemented the Problem-Based Learning (PBL) model in thermodynamics teaching and learning process, with aim to improve their students' conceptual understanding and argumentation skills. Sari et al. (2023) carried out an experimental study using a quasi-experimental pre-test–post-test design, which divided students into an experimental and a control group. From this study, the experimental group showed significant gains when compared to the control group. Thus, this study concluded that PBL is an effective strategy to implement in thermodynamics teaching and learning process, though its success requires supportive conditions. Sari et al. (2023) also recommended that further research exploring PBL across disciplines, integration with technology, and alternative assessment methods.

Zhang et al. (2021) highlighted that the transformation of engineering education through computer and mobile technologies utilizes computational tools such as Microsoft Excel. This study reviewed a student-centred methodology where students developed their own computational tool in a course on Power Generation Systems based on thermodynamics principles and equations. The advantage of this tool was to reduce time spent on students' manual calculations and also focus on design-oriented problems, parametric analysis, and system performance visualization. Both students and instructors reported that this approach enhanced understanding of energy system concepts, improved engagement, and made the course more dynamic. The study concluded that self-developed computational tools can significantly enrich students' learning experiences in energy-related courses and could be promoted to develop more such tools even in other subjects.

Acevedo et al. (2020) introduced an e-learning educational package called TermolabUA, which integrates three programs: VOLCONTROL, CarnotCycle, and CombustionUA. This educational package was designed to enhance undergraduate students' understanding of thermodynamics concepts, improve cognitive competencies (interpreting, arguing, proposing), and support interactive exploration of case studies traditionally taught manually. Across workshops, students using the software achieved significantly higher grades compared to manual problem-solving, with all results showing p-values < 0.05. The software improved cognitive skills in four areas: argumentative claim, modelling, interpreting data/information, and organization, thereby reducing the gap due to the limitations of traditional textbook case studies. Therefore, Acevedo et al. (2020) concluded that this educational package significantly motivated students to participate in self-training and improved their learning outcomes as well.

According to Arce & Vieira Freire (2017), in their work on Thermodynamics Simulation of Steam Power Cycles using Graphical Unit Interface (GUI)-MATLAB Interfaces that this program can simulate various Rankine cycle configurations, provide key parameters, including the required heat input to the boiler, the work produced by the turbine, the work needed in the feed pumps, and the cycle's thermal efficiency. This program can show reliable results, improve the functions of the equipment in these thermodynamics cycles, and become a valuable tool for educators in teaching the courses of Applied Thermodynamics.

According to Normah Mulop et al. (2012), engineering students face global challenges in learning the thermodynamics subject, and various existing teaching approaches also had been designed to address these difficulties. Methods included blended learning, active learning, computer-based instruction, virtual labs, and specialized software tools (e.g., TESTTM). The latest methods mentioned in their review are Instructional Courseware in Thermodynamics Education (by Liu, 2009), A Blended Learning Approach (by Bullen & Russell, 2007), and Virtual Assembly – A Web-Based Student Learning Tool (by Chaturvedi et al., 2007). The review evaluated these approaches based on system characteristics, effectiveness, skill development, and student feedback. Findings showed that most of these methods developed by computer technology and multimedia improved student performance, enhanced skill acquisition, and received positive feedback from learners, demonstrating their potential in strengthening thermodynamics education.

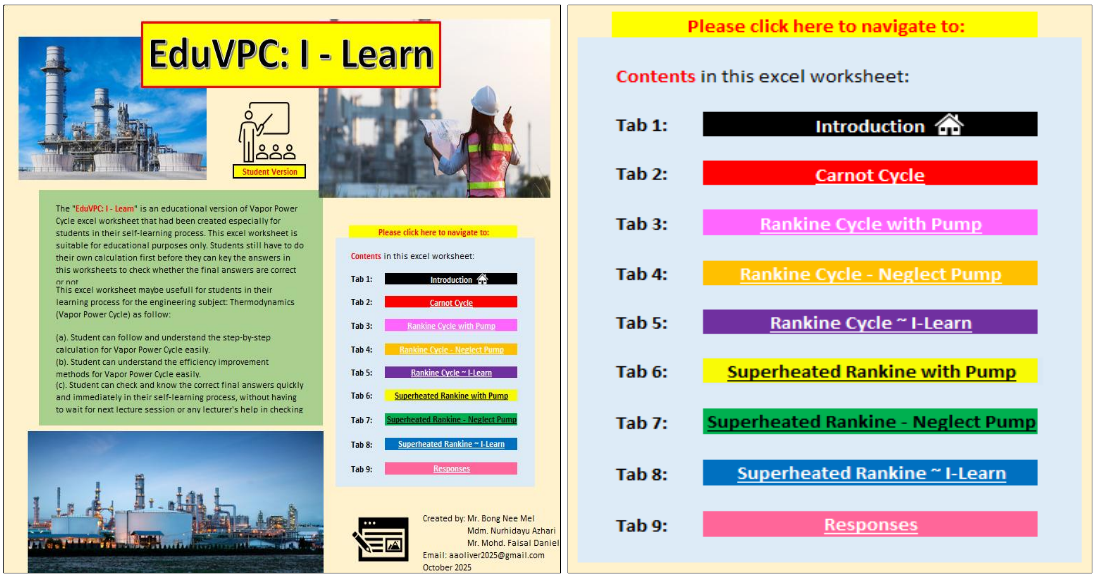
El-Awad & Seory (2012) in their work to automate the data interpolation of thermodynamics properties, found that the method of creating Excel-based computerized thermodynamics property tables enhanced with Visual Basic for Applications (VBA) functions was really important in helping students learning thermodynamics. Unlike conventional property tables, these tools enable students to perform sensitivity and optimization analyses of complex thermodynamics systems with minimal programming effort. The approach was demonstrated through the analysis of a gas-turbine cycle with intercooling, reheating, and regeneration, showing that the Excel tool produced more accurate results than the traditional constant-specific heat method. With the integration of Excel Solver, students can also optimize system parameters—such as compressor pressures—to improve efficiency. The study stresses that these computerized tables can serve as effective teaching aids, combining the educational value of traditional property tables with the flexibility of computational analysis.

Liu (2011) developed an instructional courseware in thermodynamics education for solving three types of fundamental thermodynamics problems, including the analysis of basic thermodynamics cycles. This courseware was developed using C# programming language based on the theories and algorithms related to problem-solving. According to Liu (2011), the use of this courseware in teaching thermodynamics courses by lecturers can improve students' problem-solving skills and help them better understand and master the fundamental thermodynamics laws. Therefore, educators can apply this instructional courseware in thermodynamics education due to its simplicity and practical tools in enhancing teaching quality, besides boosting students' learning process.

Most of the prior works highlighted that the innovative materials used by thermodynamics students in the teaching and learning process were developed using computer software, mobile technology, or e-learning courseware. Therefore, the authors also developed an educational Excel-based self-learning material, named *EduVPC: i-Learn* (The Vapor Power Cycle Self-Learning Kit – For Students). This Excel tool is designed to help students learn and practice calculations, verify calculation results immediately, and boost their understanding of the vapor power cycle during independent learning. Besides, the authors also conducted experimental research for the effectiveness of the *EduVPC: i-Learn* among thermodynamics students in Politeknik Kuching Sarawak, followed most of the prior works that suggested the most suitable study was in the form of experimental research.

3. Innovation Description

EduVPC: i-Learn is the Vapor Power Cycle Self-Learning Kit designed for student use. This Excel-based innovative material contents of calculation of the Carnot cycle, Rankine cycle and superheated Rankine cycle. Besides, the learning of the methods to improve the Rankine and superheated Rankine cycle's efficiency are included in this innovative material too. Figure 1 below illustrates some of the contents of this innovative material, which were introduced, guided, and facilitated for the experimental group during their regular weekly lessons.


EduVPC: I - Learn

Student Version

The "EduVPC: I - Learn" is an educational version of Vapor Power Cycle excel worksheet that had been created especially for students in their self-learning process. This excel worksheet is suitable for educational purposes only. Students still have to do their own calculation first before they can key the answers in this worksheets to check whether the final answers are correct or not.

This excel worksheet maybe usefull for students in their learning process for the engineering subject: Thermodynamics (Vapor Power Cycle) as follow:

(a). Student can follow and understand the step-by-step calculation for Vapor Power Cycle easily.
(b). Student can understand the efficiency improvement methods for Vapor Power Cycle easily.
(c). Student can check and know the correct final answers quickly and immediately in their self-learning process, without having to wait for next lecture session or any lecturer's help in checking

Please click here to navigate to:

Contents in this excel worksheet:

Tab 1: Introduction
Tab 2: Carnot Cycle
Tab 3: Rankine Cycle with Pump
Tab 4: Rankine Cycle - Neglect Pump
Tab 5: Rankine Cycle ~ I-Learn
Tab 6: Superheated Rankine with Pump
Tab 7: Superheated Rankine - Neglect Pump
Tab 8: Superheated Rankine ~ I-Learn
Tab 9: Responses

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October 2025

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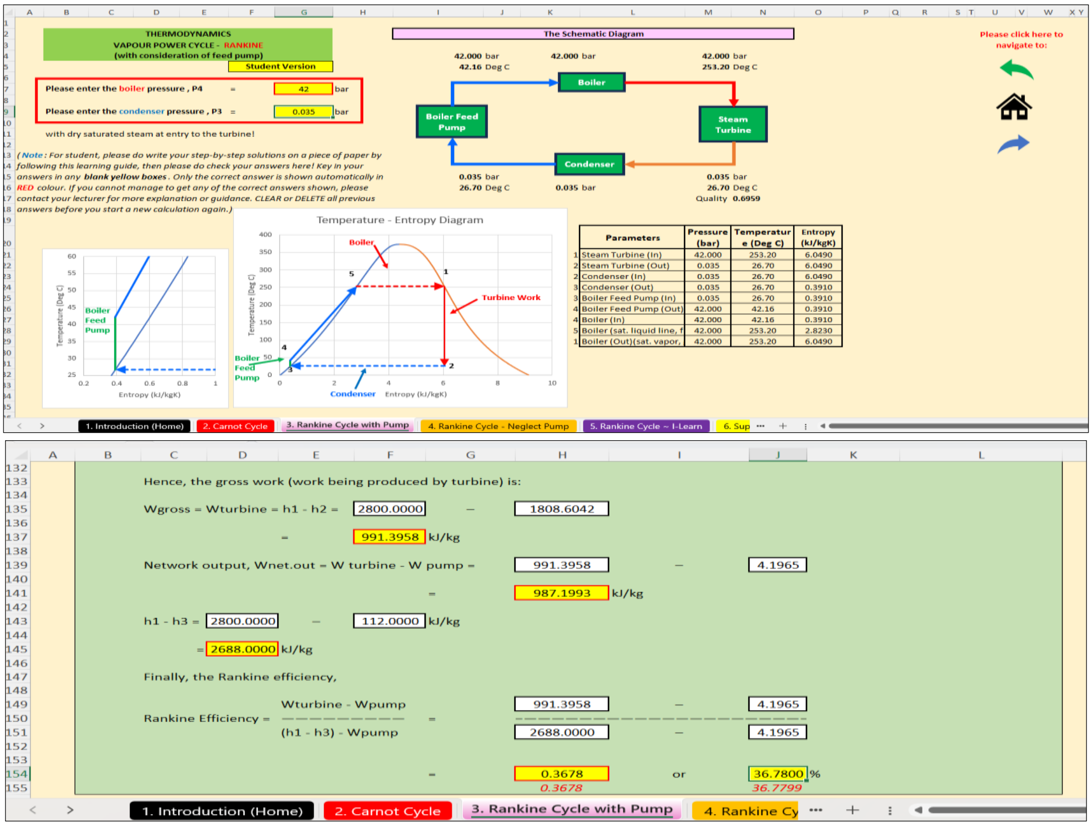
Tab 9: Responses

Figure 1: Selected contents of *EduVPC: i-Learn* implemented and used by the experimental group.


THERMODYNAMICS
VAPOUR POWER CYCLE - RANKINE
(with consideration of feed pump)
Student Version

Please enter the boiler pressure , P4 = 42 bar
Please enter the condenser pressure , P3 = 0.035 bar

with dry saturated steam at entry to the turbine!

(Note : For student, please do write your step-by-step solutions on a piece of paper by following this learning guide, then please do check your answers here! Key in your answers in any **blank yellow boxes** . Only the correct answer is shown automatically in RED colour. If you cannot manage to get any of the correct answers shown, please contact your lecturer for more explanation or guidance. CLEAR or DELETE all previous answers before you start a new calculation again.)

The Schematic Diagram

	Parameters	Pressure (bar)	Temperature (Deg C)	Entropy (kJ/kgK)
1	Steam Turbine (In)	42.000	253.20	6.0490
2	Steam Turbine (Out)	0.035	26.70	6.0490
2	Condenser (In)	0.035	26.70	6.0490
3	Condenser (Out)	0.035	26.70	0.3910
3	Boiler Feed Pump (In)	0.035	26.70	0.3910
4	Boiler Feed Pump (Out)	42.000	42.16	0.3910
4	Boiler (In)	42.000	42.16	0.3910
5	Boiler (sat. liquid line, f	42.000	253.20	2.8230
1	Boiler (Out)(sat. vapor,	42.000	253.20	6.0490

Hence, the gross work (work being produced by turbine) is:

Wgross = Wturbine = h1 - h2 = 2800.0000 – 1808.6042
= 991.3958 kJ/kg

Network output, Wnet.out = W turbine - W pump = 991.3958 – 4.1965
= 987.1993 kJ/kg

h1 - h3 = 2800.0000 – 112.0000 kJ/kg
= 2688.0000 kJ/kg

Finally, the Rankine efficiency,

Rankine Efficiency = Wturbine - Wpump / (h1 - h3) - Wpump = 991.3958 – 4.1965 / 2688.0000 – 4.1965

= 0.3678 or 36.7800 %
0.3678 36.7799

Figure 2: Some contents from the *EduVPC: i-Learn* that the students used.

In the Excel workbook application, *EduVPC: i-Learn*, students are required to do a complete calculation on a piece of paper, such as reading steam properties from the steam table, using a calculator to obtain answers, and doing the step-by-step solutions. Once the calculations are completed, students enter their answers into the designated boxes in the workbook, from the beginning to the end of the solution process. The innovative material then displays the final answer, which students can check to determine if it is correct or incorrect. This kind of design prevents students from directly accessing the complete solutions and answers without first attempting the calculations themselves. Therefore, students are encouraged to actively engage in the learning process by following the step-by-step approach recommended in *EduVPC: i-Learn*. Some of these contents in this innovative material used by the students in their independent learning was shown in Figure 2.

4. Methodology

This study employed an experimental quantitative research design with two groups of respondents. The experimental group consisted of students who learned the vapor power cycle in the thermodynamics course with the support of the innovative Excel-based material, *EduVPC: i-Learn*, in addition to their regular lessons. The control group consisted of students who attended only regular lessons without the support of *EduVPC: i-Learn*. Both groups of students (Session I: 2025/2026) were taught by the authors and other lecturers with relevant expertise, ensuring consistent delivery and ease of control and observation. A series of lessons and tutorials related to the vapor power cycle were implemented for the experimental group, incorporating *EduVPC: i-Learn* as their self-learning kit.

A self-assessment consisting of structured calculation questions was administered to both groups twice: a pre-test at the beginning of the teaching and learning process (before the intervention) and a post-test at the end of the process (after the intervention). The purpose of this assessment was to measure students' mastery and achievement in the vapor power cycle topic.

The main objective of this study was to evaluate whether the use of *EduVPC: i-Learn* had a significant effect on students' learning outcomes, and to determine whether positive improvements occurred between the experimental and control groups. Data were analysed using descriptive statistics, a one-sample t-test, and an independent-samples t-test.

The hypotheses tested in this study were as follows:

- Null hypothesis (H_0): There is no significant improvement in achievement for vapor power cycle topic (applicable to both the experimental and control groups).
- Alternative hypothesis (H_a): There is a significant improvement in achievement for vapor power cycle topic (applicable to either the experimental or control groups).

Figure 3 illustrates the scenario of the experimental group, which engaged in teaching and learning activities during their weekly regular lessons, supported by the *EduVPC: i-Learn* innovative material. Students in this group studied the calculations of a vapor power cycle aided by *EduVPC: i-Learn* on their own devices, such as laptops, tablets, or smartphones.

Figure 3: The experimental group engaged in teaching and learning activities supported by the *EduVPC: i-Learn* innovative material.

5. Discussion and Conclusion

Table 1 shows the descriptive data of respondents according to their assigned group with the pre-test and post-test mean scores in this study. From this table, there were a total of 53 thermodynamics innovative-tool-treated-students assigned in the experimental group while the control group consisted of other thermodynamics classes with a total of 62 students who just attended their regular lessons only. As could be seen, the mean scores of pre-test and post-test for the experimental group were 12.43 and 18.79 respectively. At the same time, the mean scores of pre-test and post-test for the control group were 10.65 and 16.35 respectively. This result is also presented clearly in Figure 4. The findings indicated that the experimental group had higher mean scores in post-test than the control group. In addition, from the normalized gain (N-gain) analysis, the experimental group achieved a score of 0.84, which exceeds the threshold of 0.7 and thus indicates a high gain, while the control group scores 0.61, classified as a medium gain (0.3–0.7). According to Hake's (1998) classification, values above 0.7 represent high gains, means that the instructional intervention (the innovative material of *EduVPC:i-Learn*) was effective in facilitating substantial learning progress among the experimental group. Thus, it could be concluded here that there was a better improvement in the thermodynamics - vapor power cycle's score achieved by the experimental group than the control group.

Table 1: Mean score and N-gain for both groups of respondents in pre-test and post-test.

Group	**Mean Scores**			
	Pre-test	**Post-test**	**Difference**	**N-Gain**
Experimental (N=53)	12.43 (6.581)	18.79 (2.913)	6.36	0.84 (High)
Control (N=62)	10.65 (5.792)	16.35 (5.142)	5.70	0.61 (Medium)

Note: Standard deviations are shown in brackets.

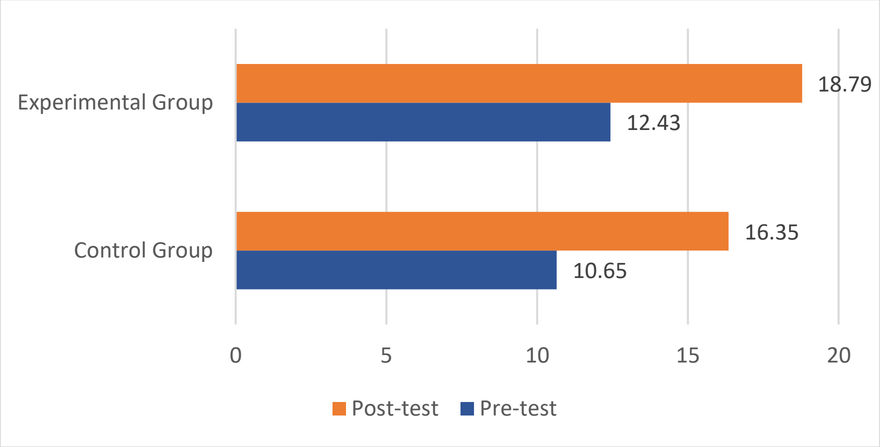


Figure 4: Self-assessment means scores for both groups of students measured before and after the treatment.

Table 2 illustrates the vapor power cycle self-assessment (post-test) scores for both groups of students in this study with test value of 16. From Table 2, the result indicated that the experimental group had achieved higher post-test performance (M = 18.79, SD = 2.913) than found in the population, t (52) = 6.979, p = .000 < .05. Thus, the null hypothesis in this study would be rejected. Hence, for the conclusion, there was a significant improvement for the experimental group after treatment. Meanwhile, for the control group, they had achieved the post-test performance (M = 16.35, SD = 5.142) with t (61) = 0.543, p = 0.589 > .05. This result indicated that the null hypothesis in this study would be accepted. Thus, for the conclusion, there was no significant attainment improvement found for the control group.

Table 2: Hypothesis testing for self-assessment score in post-test, with One-Sample Test.

	Test Value = 16					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Experiment (N=53)	6.979	52	.000	2.79245	1.9896	3.5953
Control (N=62)	.543	61	.589	.35484	-.9509	1.6606

Table 3 presents the vapor power cycle self-assessment scores for both groups of students in this study analysed by method of the independent sample t-test. From Table 3, the result indicated that, there was no statistically significant difference in the score of the pre-test for control group (M=10.65, SD=5.792) and experimental group (M=12.43, SD=6.581) with t (104.576) = 1.528, p = .130. This indicated that before the treatment process had been implemented, both the control and the experimental group showed no statistically significant difference in vapor power cycle learning and achievement, or they started at a statistically similar level. Meanwhile, there was a statistically significant difference in the vapor power cycle self-assessment scores of the post-test for control group (M = 16.35, SD = 5.142) and experimental group (M = 18.79, SD = 2.913) with t (99.028) = 3.183, p = .002, with the mean difference of 2.44 and a 95% CI [0.92, 3.96], indicates that students in the experimental group performed significantly better after the treatment process had been implemented in vapor power cycle learning than the control group. Therefore, the alternative hypothesis with the statement of “There is a significant improvement in achievement for the experimental group.” was accepted. Overall, these findings provide evidence that the innovative material of *EduVPC:i-Learn* contributed to meaningful learning gains.

Table 3: Hypothesis testing for self-assessment achievement, with Independent Sample t-Test.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Pre-test	Equal variances assumed	6.091	.015	1.543	113	.126	1.78074	1.15379	-.50512	4.06659
	Equal variances not assumed			1.528	104.576	.130	1.78074	1.16542	-.53018	4.09165
Post-test	Equal variances assumed	22.023	.000	3.056	113	.003	2.43761	.79757	.85749	4.01774
	Equal variances not assumed			3.183	99.028	.002	2.43761	.76584	.91803	3.95720

As a conclusion, the above results showed that there was a significant attainment improvement for the experimental group (students with their regular-lessons and aided by the innovative material of *EduVPC: i-Learn* as well) than the control group (conventional-regular-lessons students only). This result was supported by the previous studies of Arwizet Karudin et al. (2024), Fiandini et al. (2024), Domínguez et al. (2023), Sari et al. (2023), Zhang et al. (2021), Acevedo et al. (2020), Arce & Vieira Freire (2017), Normah Mulop et al. (2012), El-Awad & Seory (2012) and Liu (2011) that the experimental group in the study could achieve better performance and being motivated in their learning process than the control group once the innovative and interactive teaching and learning is implemented. The authors also agreed with all the above researchers that the special innovative material could be a very valuable tool to enhance students' learning abilities if implemented properly and accordingly in education especially the engineering subject of thermodynamics. In addition, the innovative material which developed as an e-learning courseware or mobile application might easily attracting the new generation engineering students to promote their self-learning and enhance their course outcomes effectively.

Furthermore, from these encouraging findings, the authors would like to suggest that the innovative and interactive materials use in the teaching and learning process could be promoted by favourable to develop even in other engineering subjects or across disciplines. The aims are to motivate students, to promote self-learning, to improve understanding and to enhance course outcomes.

Acknowledgement

The authors sincerely acknowledge the lecturers of the Mechanical Engineering Department, Politeknik Kuching Sarawak, for their invaluable guidance, constructive feedback, and continuous support throughout the conduct of this study. The authors also extend their gratitude to the students who participated in this research, whose cooperation and engagement with the innovative material *EduVPC: i-Learn* provided essential insights and made the study possible. The collective contributions of both lecturers and students were instrumental in advancing the exploration of independent learning practices in thermodynamics education.

Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this study.

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