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Innovation in Teaching Methodology: Level of Student Acceptance of 'Boyles Law Apparatus' Teaching Aids in Thermodynamics Course

[1*]Suhaila, Mohd Sharif, [2]Mohd Fitri, Basiran, & [3]Norhazlina, Amon

[1,2,3]*Department of Mechanical Engineering*, Politeknik Port Dickson, Kampung Sungai Menyala, 71250 Port Dickson, Negeri Sembilan, MALAYSIA

**Corresponding Author: sue_msh@yahoo.com*

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Abstract: Boyle's law is used to explain the inverse relationship between pressure and the volume of gas at a constant temperature. This law states that when the pressured container is filled by increasing gas, thus the total volume will decrease. This research paper aims to study the level of student acceptance of teaching based on teaching aids (TA) Boyle's Law Apparatus (BLA) in the teaching and learning for the DJJ20063 Thermodynamics course. The questionnaire study was distributed to 66 respondents, namely Port Dickson Polytechnic's students of semester 2, Diploma in Mechanical Engineering program December 2019 session who involved in lectures where TA is used to give the students a clear vision in understanding the concept of Boyle Law in the topic of Perfect Gas. The data were analysed by using SPSS software through descriptive analysis statistics. The results of the study showed that the level of effectiveness of this TA is at a high level with an average mean score of 3.70 and standard deviation 0.447. Therefore, studies showed that the use of this teaching aids among students provides a better understanding, especially on the topic of Perfect Gas compared to teaching methods without the teaching aids that had been produced before. Through this method as well, the study found that students' interest and determination to deepen a lesson can be nurtured in more depth.

Keywords: Teaching Methodology, 'Boyle's Law' Teaching Aids, Thermodynamics.

1. Introduction

The basic concepts of engineering thermodynamics have not changed significantly for decades, and engineering thermodynamics is still a fundamental course for all engineering students (Huang & Gramoll, 2004). Thermodynamics is one of the subjects that need to be studied in the field of Mechanical Engineering. Thermodynamics is also a branch of physics related to heat, work, and temperature, and its relationship to energy, radiation, and the physical properties of matter. Thermodynamics is not only applying to a wide range of topics in science and engineering, especially physical chemistry, chemical engineering, and mechanical engineering, but also in other complex areas such as meteorology. Therefore, with the importance of thermodynamics in the field of engineering and daily human life, this field and knowledge of thermodynamics need to be appreciated and mastered by the students and later will apply that knowledge in work and daily life.

Teaching aids consisting of tangible objects are helpful for students to learn the abstract concepts in science as they enable students to visualize the concepts (Chou et al., 2015). Research on the development of experimental kits for science learning has also been conducted by several researchers (Saputri & Dewi, 2014; Preliana, 2015; Budiyanto, 2015; Yulianti, Zulkardi & Siroj, 2010; Hasbi, 2015) to produces feasible experiment kit which has a positive effect on learning outcomes. Therefore, in giving more understanding to the students, this 'Boyle's Law Apparatus Experiment' was developed among the students for the DJJ20063 course in Thermodynamics subject. 'Boyle Law apparatus experiment' is one of the tools used in the classroom during lectures for teaching and learning to give students a better understanding of Boyle Law for the topic of a perfect gas. Boyle's Law is one of the few perfect gas laws that discribes the inverse relationship between pressure and absolute volume of a gas if the temperature is maintained uniformly in a closed system.

1.1. Problem Statement

Over the past four decades, physics education research has investigated students' misconceptions in diverse topics, including thermal physics. Many studies in thermal physics have covered topics such as heat and temperature (Sözbilir, 2003), thermodynamics and heat transfer (Vigeant, Prince & Nottis, 2009), heat transfer mechanisms and elementary kinetic theory (Pathare & Pradhan, 2010), thermodynamic processes and the implications (Georgiou et al., 2009; Georgiou & Sharma, 2012), the first law of thermodynamics relating work to the adiabatic compression of an ideal gas

(Loverude, Kautz & Heron, 2002), entropy and the second law of thermodynamics (Christensen, Meltzer & Ogilvie, 2009).

The teaching and learning of engineering courses are always challenging due to its complex and abstract nature, and the mathematics involved (Chowdhury et al., 2019). The important thing in the given topic is a basic conceptual understanding. It is challenging if students continue the lecture without a clear and accurate reference as well as no help from teaching aids used by lecturers. If the student's ability to remember is decent, then the student can master what the lecturer delivered effectively. Through experience, while delivering lectures in class, there are handfuls of students who still do not understand and are slow to master what the lecturer shared. Loverude Kautz & Heron (2002) discussed students' misconceptions of temperature, heat, work and internal energy. Therefore, to identify the effectiveness of this matter whether the development of teaching aids is relevant as well as achieving the objectives or not then the study is conducted to ensure it.

To provide an effective presentation for the students to understand better on the topic of Boyle's Law in the perfect gas course DJJ20063 Thermodynamics, a teaching aid tool needs to be developed to help the students in getting more clearly the concept to be conveyed. It can also help the lecturers in delivering lectures due to the lack of special practical equipment for the DJJ20063 Thermodynamics course for the topic of a perfect gas. Additionally, students also do not clearly understand the theory of Boyle's Law as possibly because the lecturer still does not have the appropriate teaching aids to give a better explanation of Boyle Law on the topic of a perfect gas. Therefore, there are two objectives will be measure in this study. There are:

- To determine the level of student acceptance of the use of Boyle's Law teaching aids for the DJJ20063 Thermodynamics course in teaching and learning.
- To identify students' interest in the use of Boyle's Law teaching aids in the DJJ20063 Thermodynamics course.

While the limitation and scope of this study was to identify the level of student acceptance of teaching aids used on semester 2 students in the Department of Mechanical Engineering Port Dickson Polytechnic. A total of 66 respondents from the Diploma in Mechanical Engineering program were involved in this study. The scope of this study is to focus on the topic of Boyle's Law perfect gas, one of the topics found in the DJJ20063 Thermodynamics course.

2. Literature Review

Thermodynamics is determined to be one of the most challenging and abstract disciplines of the physical sciences (Dukhan, 2015). Manteufel (1999) described thermodynamics as the gateway course in mechanical engineering in the sense that student's performance in thermodynamics correlates well with how the student does in the rest of the courses in the curriculum. In the field of thermodynamics, there are many laws and among the crucial ones is Boyle's Law. Boyle's Law, also called Mariotte's law, a relation concerning the compression and expansion of a gas at a constant temperature. This empirical relation, formulated by the physicist Robert Boyle in 1662, states that the pressure (p) of a given quantity of gas varies inversely with its volume (v) at constant temperature; i.e., in equation form, PV = k, a constant. The law can be derived from the kinetic theory of gases assuming a perfect (ideal) gas. Real gases obey Boyle's law at sufficiently low pressures, although the product PV generally decreases slightly at higher pressures, where the gas begins to depart from ideal behaviour.

Close scrutiny of the literature reveals that in addition to conceptual difficulties, students have difficulty integrating concepts and principles and recognizing their relevance in solving problems (Lape, 2012). As a first step in solving thermodynamics learning problems, one must understand, correctly frame, and identify the root causes of these problems. It is the foundation for eradicating these problems. It also can inform and positively influence new instructional strategies (Dukhan, 2015). Meltzer (2015) said that students have difficulties with the concepts of heat, work, cyclic processes, as well as the first and second laws. Students who can solve textbook problems may still give incorrect answers to conceptual questions in thermodynamics (Abulencia, Vigeant & Silverstein, 2013). Therefore, to give students a good understanding of Boyle's law, various methods need to be used to help the students not only on teaching aids but also delivery methods are necessary to support the success of the presentation. Therefore, communication is essential in every lecture session conducted. The level of achievement in the information given by the lecturers during their lectures will also depend on effective communication. Therefore, teaching tools were used, especially tools or materials that involve the senses such as real equipment, colours, and also the tool that can be felt and listened can provide a new experience. In turn, this will make the lecture sessions even more interesting and efficient.

The method or method of matching the technique of delivery in the classroom will make the lecture or class session good or not (Chowdhury & Shahabuddin, 2007). Therefore, with the above stated, the use of TA materials in the form of pictures and symbols gives a better impact in giving more understanding to students in contrast to verbal delivery as it is more challenging and not able to state an accurate picture to students- students. Because of that, the lecturer's teaching plan should be well planned to coincide with the level of students and further supported with teaching aids. It is intended to stimulate student development to something even better. Therefore, that is why TA is crucial in every lecture session held to trigger students to be more interested in learning. Apart from that, guidance should be given to students to develop maximum self-potential to gain skills and knowledge (Rashidi & Razak, 1996). On behalf of lecturers or

teachers, lecture delivery strategies should follow the correct techniques and strategies concerning appropriate educational theories (Mok, 2000). From what was presented by previous researchers, this clearly shows and states that TA is a material to facilitate the delivery and implementation of lectures. Therefore, the conclusion is that TA is very significant to lecturers in supporting them to provide the best delivery results to students.

As a conclusion, this study was probably provided an importance for both lecturers and students. They will take an information on the level of student acceptance in evaluating the level of effectiveness of teaching aids developed. Secondly, it is important to identify students' problems in receiving lessons delivered by lecturers in the classroom. And lastly, it is important that to assist lecturers in improving the quality of teaching aids so that it is appropriate for students.

3. Methodology

3.1 Population and Sample

The population of this study is semester 2 students for the December 2019 Session of the Department of Mechanical Engineering at Port Dickson Polytechnic. In considering the size of population, this study examined samples taken with a random sampling technique. The sampling involves 3 programs, namely the Diploma in Mechanical Engineering (DKM), Diploma in Mechanical Engineering - Manufacturing (DTP) and also the Diploma in Mechanical Engineering-Automotive (DAD). Therefore, the students in each of these 3 programs are members of the population. All students for these three programs were 80, but only 66 were randomly selected as the study sample (Krejcie & Morgan, 1970).

3.2 Instrumentation

The research tool used is in the form of a questionnaire. It is used to identify the level of effectiveness of the use of teaching aids among students taking the DJJ 20063 Thermodynamics course. The questionnaire consists of fifteen (15) questions where it refers to the student's acceptance of the teaching aids 'Boyles Law Apparatus Experiment'. The 4 (four) level Likert scale was used for the data evaluation process in the questionnaire conducted in Table 1 below.

Table 1: The 4 (four) level Likert scale

Scale	Interpretation
1	Strongly disagree
2	Disagree
3	Agree
4	Strongly agree

The measurement scale of the mean score inclination level is referred based on the interpretation of the mean score for the Likert scale as shown in table 2 below.

Table 2: Levels of mean score inclination (Source: Landell, 1977)

Mean Score	Level
1.00 – 2.33 2.34	Low
– 3.67	Moderate
3.68 – 5.00	High

4. Results And Discusion

4.1 Data Analysis: Part A - Background of Respondents

As a result of the analysis conducted, the demographics of the respondents of semester 2 students of the Diploma of Mechanical Engineering program at Port Dickson Polytechnic consists of 69.7 % men and 30.3% women out of 58 respondents in all. Figure 3 shows the results of the demographic analysis of the gender of the respondents using IBM SPSS Version 26 statistical software.

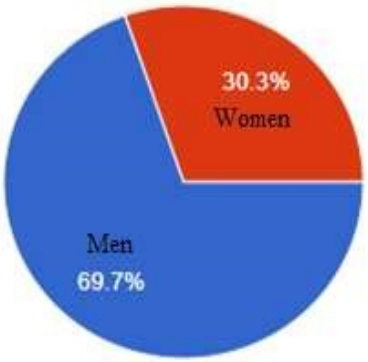

Figure 3. Gender Demographic Analysis

The Malays were the highest at 90.9%, Indian 6.1%, Chinese 1.5%, and the other with 1.5% as shown in Figure 4.

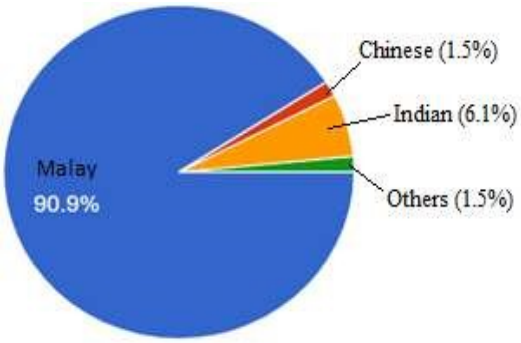

Figure 4. Races Demographic Analysis

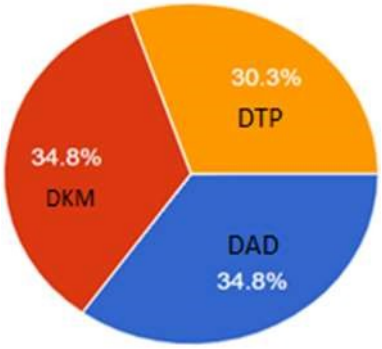

Figure 5. Program Demographic Analysis

As for the fraction of the program, the program Diploma in Mechanical Engineering (DKM with 23 respondents (34.8%) is the same as the program Diploma in Mechanical-Automotive Engineering (DAD) with 23 respondents (34.8%) and (Diploma in Mechanical Engineering - Manufacturing (DTP) with 20 respondents (30.3%) as shown in Figure 5.

4.2 Study Analysis: Part B - Based on Study Questions

Based on the research questions in the questionnaire used, a summary of the analysis level of student acceptance of teaching aids 'Boyle's Law Apparatus' can be shown as in Table 6 below:

Table 6: Student acceptance of BLA Teaching Aids

No Item	Variables	Strongly Disagree	Disagree	Agree	Strongly Agree	Std. Dev.	Mean	Level
		f %	*f* %	*f* %	*f* %			

No Item	Variables	Strongly Disagree *f* %	Disagree *f* %	Agree *f* %	Strongly Agree *f* %	Std. Dev.	Mean	Level
B1	Do you agree that this Thermodynamics course is difficult?	0 0%	0 0%	2 3%	64 97%	0.173	3.97	High
B2	The teaching aids used by the lecturers were very important in helping me master the topic of Boyle's Law learning.	0 0%	0 0%	21 31.8%	45 68.2%	0.469	3.68	High
B3	Are you more interested and focused if the lecturer uses teaching aids in the topic of Boyle's Law?	0 0%	0 0%	18 27.3%	48 72.7%	0.449	3.73	High
B4	The lecturer's explanation will be clearer and more steady when the lecturer uses TA BLA during the teaching and learning sessions.	0 0%	0 0%	26 39.4%	40 60.6%	0.492	3.61	Moderate
B5	TA BLA used by lecturers is very interesting and easy for students to understand.	0 0%	0 0%	22 33.3%	44 66.7%	0.475	3.67	Moderate
B6	TA BLA used by lecturers can stimulate the mind and add my ideas to explore something new.	0 0%	0 0%	24 36.4%	42 63.6%	0.485	3.64	Moderate

B7	I am more interested in mastering the topic of a perfect gas with the use of TA BLA.	0 0%	0 0%	22 33.3%	44 66.7%	0.475	3.67	Moderate
B8	The use of TA BLA helps me remember the concepts and theories of Boyle's Law on the topic of an ideal gas.	0 0%	0 0%	26 39.4%	40 60.6%	0.492	3.61	Moderate
B9	The use of ABM BLLA increased my confidence to answer questions involving Boyle's Law.	0 0%	5 7.6%	28 42.4%	33 50%	0.634	3.42	Moderate
B10	I am not bored and focused on learning the Boyle's Law topic with TA BLA used by lecturers.	0 0%	0 0%	15 22.7%	51 77.3%	0.422	3.77	High
B11	I understand and know how to use TA BLA without the help of a lecturer.	0 0%	0 0%	23 34.8%	43 65.2%	0.480	3.65	Moderate
B12	Is TA BLA used by lecturers effective in creating interesting and enjoyable teaching and learning environment?	0 0%	0 0%	16 24.2%	50 75.8%	0.432	3.76	High
B13	TA BLA was able to solve my problem to understand and master the topic of Boyle's Law.	0 0%	0 0%	16 24.2%	50 75.8%	0.432	3.76	High
B14	Do you agree that lecturers should provide TA for teaching and learning effectiveness?	0 0%	0 0%	16 24.2%	50 75.8%	0.432	3.76	High

B15	I am more interested and focused on learning with the use of TA in the form of experimental or visual than the teaching and learning process using the method of 'chalk and talk' or whiteboard.	0 0%	0 0%	10	15.2%	56	84.8%	0.361	3.85	Moderate
	Overall Average	**0.0%**	**0.4 %**	**28.8%**		**0.447**		**3.70**	**High**	

From the analysis done using SPSS Version 26 and summarized as Table 6 above, 97% of students strongly agree with item B1 said that the topic of Boyle's Law in Thermodynamics course is a topic that is very difficult to master and understand while the rest with 3% states agree regarding the item. B1 total of 68.2% (45 students) strongly agreed while 31.8% (21 students) stated that the TA used by the lecturers is very important in helping them to master the topic of learning Boyle's Law as in item B2.

For item B3, a total of 72.7% (48 students) strongly agree and are more interested and focused if the lecturer uses teaching aids in the topic of Boyle's Law. The remaining 27.3% (18 students) agreed with the B3 item. Next for item B4, a total of 40 students with 60.6% strongly agree that the lecturer's explanation will be clearer and more robust when the lecturer uses TA BLA during teaching and learning sessions compared to the rest with 26 students with 39.4% only agreeing with the statement. 44 students who gave a value of 66.7% stated that item B5 which is TA BLA used by the lecturers is very interesting and easy to understand. Even so, only 22 students with 33.3% only agreed with the statement of item B5.

Not only that, TA BLA used by lecturers can stimulate the mind and add ideas to students to explore something new. In this item, 42 students (63.6%) strongly agreed while the remaining 24 students (36.4%) agreed with the B6 survey questions. With the TA BLA, students are more interested in mastering the topic of perfect gas such as question B7 in the questionnaire, 22 students with 33.3% agree with the matter while the remaining 44 students strongly agree with the total 66.7% on item B7.

Concepts and theories in a topic are the basis for strengthening students' understanding. Students struggle with concepts and principles. Many of student's misconceptions are persistent (Dukhan, 2015).It showed in item B8 found in the questionnaire conducted as the analysis of the question gave a result where 40 students (60.6%) strongly agree while the remaining 26 students (39.4%) only agree on item B8 that is the use TA BLA helps them remember the concepts and theories of Boyle's Law in the topic of an ideal gas.

Another difficulty students possess is that they fail to realize the relevance of thermodynamic knowledge during the process of problem-solving (Dukhan, 2015). Once students have mastered what they have learned and a good understanding of the concepts in a topic, it will indirectly give confidence to students in applying the knowledge in answering test or exam questions. From the B9 item survey, 28 students (42.4%) agreed while the remaining 33 (50%) strongly agreed that the use of TA BLA increased their confidence to answer questions involving Boyle's Law. Even so, there are some students with overall 5 people (7.6%) who stated that they disagreed with the B9 item. It is probably because the students are more interested in answering questions on other topics that they think will give better marks if they choose the questions.

Furthermore, for item B10, 15 students (22.7%) stated that they are not bored and focused on learning the topic of Boyle's Law with TA BLA used by the lecturers while 51 students (77.3%) strongly agreed with item B10. A total of 23 students (34.8%) agreed while the remaining 43 students (65.2%) strongly agreed and understood how to use TA BLA without the help of lecturers. It is based on the question asked in item B11 in the survey conducted. Therefore, this matter has continuity with item B12 which is the process of creating a more interesting and fun teaching and learning environment in the classroom and TA BLA used by lecturers is effective because 50 students with 75.8% strongly agree with the matter while the rest with 16 students, 24.2% agreed on the B12 item.

Also, researcher like Christensen, Meltzer & Ogilvie (2009) were discovered that students misinterpreted the laws of perfect gases. Hence, efforts of improving the teaching and learning process should be made by actively involving students in building their knowledge and understanding (Hakim et al., 2019). Therefore, we can see here that TA BLA

can solve the problem of students to understand and master the topic of Boyles Law because a total of 50 students (75.8%) strongly agree while the remaining 16 students (24.2%) with the statement as in the questionnaire item B13. To support such matters as item B14, lecturers should provide ABM for the effectiveness of teaching and learning conducted due to 50 students (75.8%) who strongly agree and 16 students (24.2%) who agree with item B14.

The last question of the questionnaire, item B15, clearly shows the importance of TA BLA to support a more effective teaching and learning process where 56 students (84.8%) strongly agree while the remaining 10 students (15.2%) agree and state that they are more interested and focus on learning with the use of TA in the form of experimental or visual compared to the teaching and learning process using the method of 'chalk and talk' or whiteboard. Kulkarni & Tambade (2013) stated that teaching and learning aided by computer with animations and simulations in the classroom gives an alternative to students to understanding various alternatives of concepts through visualization of abstract concepts and graphic representation. From the complete analysis done on the survey conducted, the overall average who strongly agreed for the 15 items found in the questionnaire was 70.8% of students, agreed with 28.8% with only 0.4% stated ddisagree. This can also be shown in the average mean value obtained which is 3.70. This mean value indicates that TA BLA is at a high level referring to Table 2.

Therefore, this matter clearly shows the importance of TA BLA is very necessary to improve teaching and learning on the topic of Boyle's Law in the next Thermodynamics course TA BLA can help students in mastering what is presented by lecturers. It supports the previous study that stated for the overall solution to the problem of weak thermodynamic learning by engineering students to be effective, it must take into account the problem and the cause of the problem (Dukhan, 2015). This is also supported by Zidny et al (2019) based on the results of studies conducted with limited scale, it can also be concluded that the experimental kits can facilitate teacher to explain the chemical concepts regarding the gas laws. Students also showed a positive perception of the experiment kit, especially in increasing student interest to learn gas laws concepts. The Teacher's assessment of educative, technical, and aesthetic aspects of learning with experimental kits of ideal gas laws showed good criteria.

5. Conclusion

From the study conducted, the level of student acceptance of TA BLA for the Thermodynamics course at Port Dickson Polytechnic is at a high level. Many positive responses were given by students to the teaching aids used by the lecturers during the Thermodynamics class. Apart from that, the use of 'chalk and talk' only without using teaching aids or actual control materials will cause the lecture sessions conducted not attractive and eventually results in students' misunderstanding regarding what is presented by the lecturer.

Therefore, with the presence of TA BLA used by lecturers in Thermodynamics courses, the explanation of Boyle's Law topic will be better and in turn, will have a positive impact on the students. However, this TA BLA still needs improvement from time to time to provide better results in the future. Hopefully, this study is useful in improving the teaching and learning methods of lecturers as well as students' understanding can be improved from time to time and can deepen the field of Thermodynamics even further. Not only that, students will be happier and more motivated with more interesting and creative teaching sessions conducted by lecturers.

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