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Development of 'Boyles Law Apparatus' Teaching Aids for Thermodynamics Course: Innovation in Teaching Methodology

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Abstract: Teaching aids are among the most important instruments in providing effective delivery results as well as the best understanding to students. Therefore, this teaching aid should also be in the Thermodynamics course and among the topics whose concept is quite difficult to understand by students is Boyles Law in the topic of Perfect Gas. Boyle's law is used to explain the inverse relationship between pressure and gas volume at a constant temperature. This law states that when the pressure of the container is filled with increasing gas, then the total volume will decrease. Boyles' Law on the topic of Perfect Gas is also one of the important topics and it is the basis in Thermodynamics. This paper is about the development of Boyle's Law Apparatus (BLA) teaching aids (TA) for the DJJ20063 Thermodynamics course at Port Dickson Polytechnic which is an apparatus that can explain to students related to the basic concepts of Boyle's Law. In addition, this teaching aids can also help lecturers in providing a better understanding to students who take Thermodynamics courses. The production of this tool is not only used by lecturers in the theory class but also this tool can also be used for practical needs in the laboratory. In conclusion, a suitable apparatus for explaining Boyle's Law to students has been successfully designed and developed. In this regard, hopefully the innovation of this teaching aids will be able to benefit all parties in improving the teaching and learning system, especially for Thermodynamics course.

Keywords: Teaching and Learning, 'Boyle's Law' Teaching Aids, Thermodynamics.

1. Introduction

Education is the biggest investment of a nation and it has a major role in realizing the quality of human resources in order to be able to master and develop science and technology (Marisda, 2014). The world is moving towards competition. People struggle to learn, and to work hard to create a new learning environment. The purpose of education is not only teaching the text book and make the students understand but also adds innovative thinking creative environment and self – sufficiency (Kalyani & Rajasekaran, 2018). Therefore, this 'Boyle's Law Apparatus' was developed to meet the needs of students in the practical and learning process for the DJJ20063 - Thermodynamics course. 'Boyle's Law Apparatus' is one of the teaching aids for teaching and learning student in Boyle's Law title for the topic of perfect gas. Boyle's law is one of the perfect gas laws that discribes the inverse relationship between the pressure and the absolute volume of a gas if the temperature is maintained evenly in a closed system.

In education, student engagement refers to the degree of attention, curiosity, interest, optimism, and passion that students show when they are learning or being taught, which extends to the level of motivation (Kalyani & Rajasekaran, 2018). Teaching and learning thermodynamics involves concepts that concern most scientific domains such as physics, biology, earth science, and of course chemistry (Le Maréchal & Bilani, 2008). The topic of Boyle's Law in perfect gas is among the topics that are difficult for students to understand in the subject of Thermodynamics.

Students need to know and understand perfect gas theory as it is one of the main topics for Thermodynamics course. This project developed is a teaching aid that strengthens the theory and also students' knowledge related to perfect gas. Apart from that, among the other problem statements that are seen to result in the idea of developing this apparatus are: (1) Students do not clearly understand the theory; (2) there is no practical equipment; (3) there are no teaching aids for the topic of 'Boyle's Law'. As noted by Feisel & Rosa (2005) hands-on practical laboratories help students to understand complex theoretical problems and apply theoretical knowledge in practice.

Other than that, this apparatus is used to explain to students the basic concepts of Boyle's Law and used as a teaching aid for lecturers for the DJJ20063 Thermodynamics course for Mechanical Engineering students. The production of this tool is the result of problems faced by students who have difficulty understanding the learning process taught by lecturers related to Boyle's Law. Therefore, with the production of 'Boyle's Law Apparatus' to some extent can help improve the understanding process to students. Among the rationale to produce this equipment are:

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- Thermodynamics course lecturers can use this tool as a teaching aid in the teaching and learning of Thermodynamics courses.
- Students can understand the concepts and theories of Boyle's Law learned more clearly can further improve students' thinking ability and attract students for Thermodynamics course.
- This equipment can be used as practical equipment for Thermodynamics courses to meet the needs of the syllabus.
- Learning outcomes will be more effective because with "hands on" activities in conducting experiments can attract students.

For that reason, for reduce or settle that problem, development of Boyle's Law Apparatus teaching aids for the DJJ20063 Thermodynamic course at Port Dickson Polytechnic for the topic of Boyle's Law in the topic of perfect gas is the main objective for this research.

2. Literature Review

The teaching and learning of engineering are always challenging due to its complex and abstract nature, and the mathematics involved (Chowdhury, Alam & Mustary, 2019). The biggest challenge any teacher faces is capturing the students' attention, and putting across ideas in such a way that it stays with them long after they have left the classroom (Kalyani & Rajasekaran, 2018). Thermodynamics is determined to be one of the most challenging and abstract disciplines of the physical sciences (Dukhan, 2015). 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 relationship was also discovered by the French physicist Edme Mariotte (1676). 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. Most engineering programs especially mechanical and civil engineering need hands-on workshop facilities for running educational laboratory practices to achieve academic objectives. (Alam et al., 2007; Alam, Tang & Tu, 2004).

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). 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 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 (Hashim, Yaakub & Ahmad, 2003).

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 (Alam, Tang & Tu, 2004). 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 (Sang, 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 important for lecturers in supporting them to provide the best delivery results to students and the statement of the use of these teaching aids is also supported by Nasution (2005) where he also agrees teaching aids are useful to make learning effective and successful.

Among the Boyle's Law Apparatus products available in the market.

2.1 Horizontal Mount

Figure 1. Horizontal Mount Boyle's Law Apparatus

Designed as a smaller, more economical version of the Standard Boyle's Law Apparatus. The apparatus consists of a horizontally mounted acrylic tube with a graduated scale along one side (scale graduated from 0 to 270cm3). The tube unit is sealed by a standard gas tap next to which is mounted a standard pressure gauge. The effective length of the tube is controlled by altering the position of a rubber stopper moved via a screw thread. Users can select the effective length of the tube by positioning the stopper and closing the gas tap. The volume of the tube can be read off the scale and printed against the corresponding pressure taken from the gauge. By varying the position of the stopper Boyle's Law can be investigated. This unit has the advantage over the standard model as it does not require oil to indicate the volume of air. The tube is made out of acrylic which is known to fail 'safely' if punctured.

2.2 Digital Type

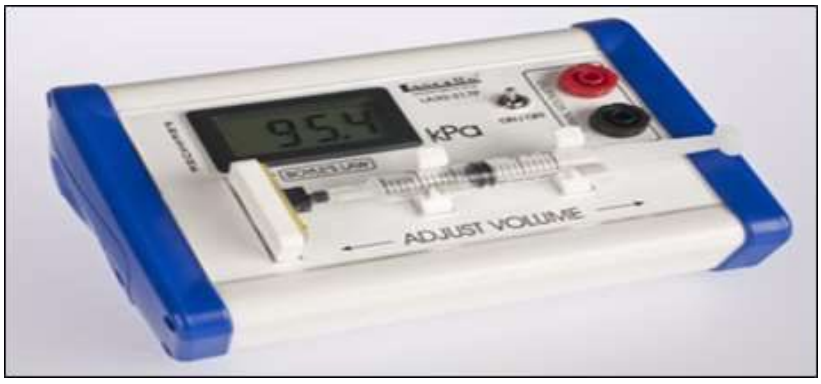

Figure 2. Digital Type Boyle's Law Apparatus

The Digital Boyle's Law Apparatus provides a self-contained, reliable, and simple way of demonstrating Boyle's Law. The volume may be reduced or increased by means of a 2.5 ml syringe connected to a digital pressure sensor. The sensor output is calibrated to display the pressure in kPa on the easy to read LCD display. There is a measurable change in pressure for every 0.1ml change in volume allowing many data points to be taken and a graph plotted to confirm Boyle's Law. For demonstration purposes two 4mm sockets are provided to allow the pressure reading to be displayed on a large demonstration voltmeter meter (not supplied) and a length of tubing is provided to allow a larger syringe to be used if necessary. Supplied with full instructions and one 9V PP3 battery.

3. Methodology

Methodology is a method to produce quality work projects through research and studies conducted on the project. In addition, methodology is also a study in the scientific field. It also means as knowledge about research to implement a project to achieve the planned goals.

3.1 Process Flowchart

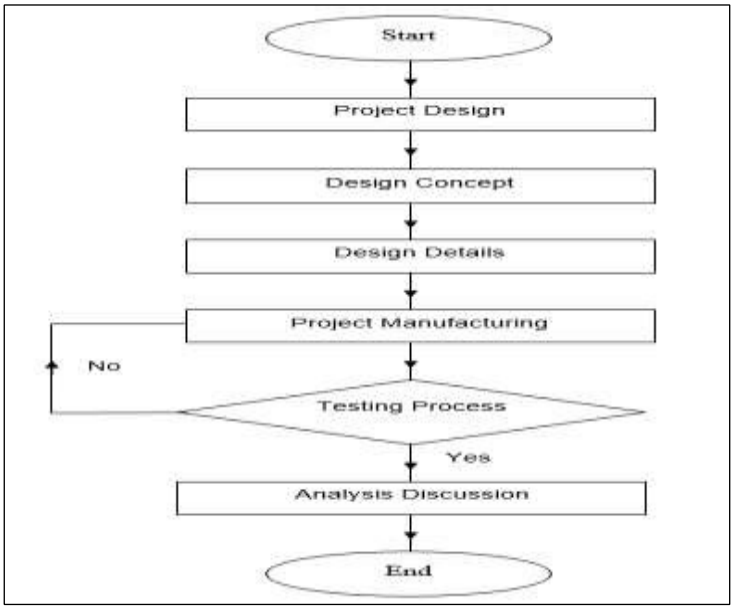

Figure 3. Methodology Process Flowchart

The methodology flow chart is a flow chart to facilitate the process of doing research and study on the "Boyle's Law Apparatus" project.

3.2 Description of Research Methodology Flow Chart Steps

3.2.1 Project Design

Project design is a step to analyse all existing problems before creating or designing a new project that can replace the existing product in order to overcome the problems that often occur on this teaching aid that is "Boyle's Law Apparatus".

3.2.2 Design Concepts

The concept of design is an important step to explain the concept of project design to be created and sketched. The best design and concept will be chosen to produce this project.

3.2.3 Detailed Design

Detailed design is the best design concept that has been selected and sketched more clearly and in detail as well as explains more clearly about the raw materials used in this project.

3.2.4 Project Implementation

Project creation is the initial step, to build a project and explain the tool installation steps on the project. The method used in the manufacture of this project is welding and, in this step, will be the result of the completed project.

3.2.5 Testing

Testing is a process in which a completed project will carry out a testing process to ensure that the completed project works successfully. Next, an analysis discussion will be conducted to analyse the problems found in the project. If testing on this project is not successful, then the project manufacturing process will be repeated to modify and repair.

3.2.6 Analysis Discussion

The analysis of the discussion is the final stage that will be conducted after the project testing is successfully implemented. Analysis will be discussed about the projects that have been made. The purpose is to find out the performance and capabilities of this "Boyle's Law Apparatus" project can be carried out.

3.3 Project Development Steps of Boyle's Law Apparatus

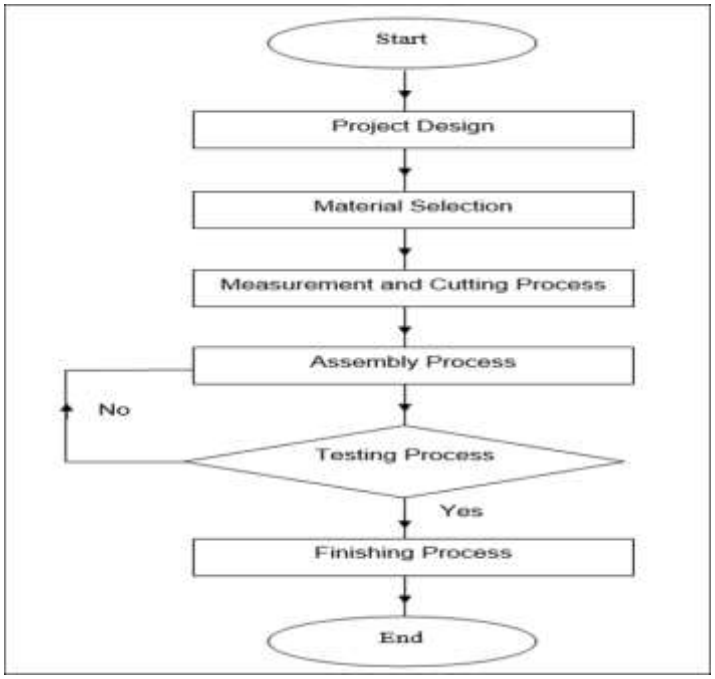

Figure 4. Project Development Steps Flowchart

3.3.1 Project Cost

Table 1: The total cost of the project

Type of cost	Total Cost
1. Pressure Gauge	RM 60.00
2. Aluminum Tank	RM 63.00
3. Pump, valve and tube	RM 45.00
4. Copper ball Valve	RM 10.00
5. Copper socket fitting	RM 14.50
6. Acrylic tube (50 cm)	RM 27.00
7. Iron plate	RM 50.00
8. Plywood	RM 40.00
9. Tools	RM 80.00
Total	**RM 389.50**

3.3.2 Project Development Process

Figure 5. The process of fitting the 'brass ball valve' to the aluminium tank

Figure 6. Plywood measurement work according to measurements has been planned as project drawings are made

Figure 7. Plywood cutting work to produce project framework and base

Figure 8. Plywood assembly work to build project framework

3.4 Design Consideration

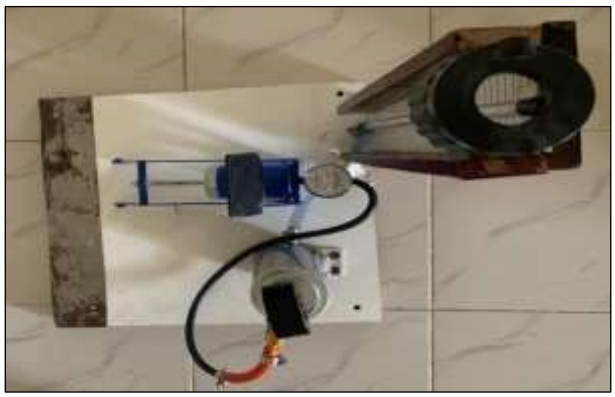

Figure 9. Top view of the apparatus

Figure 10. Front view of the apparatus

Figure 11. Side view of the apparatus

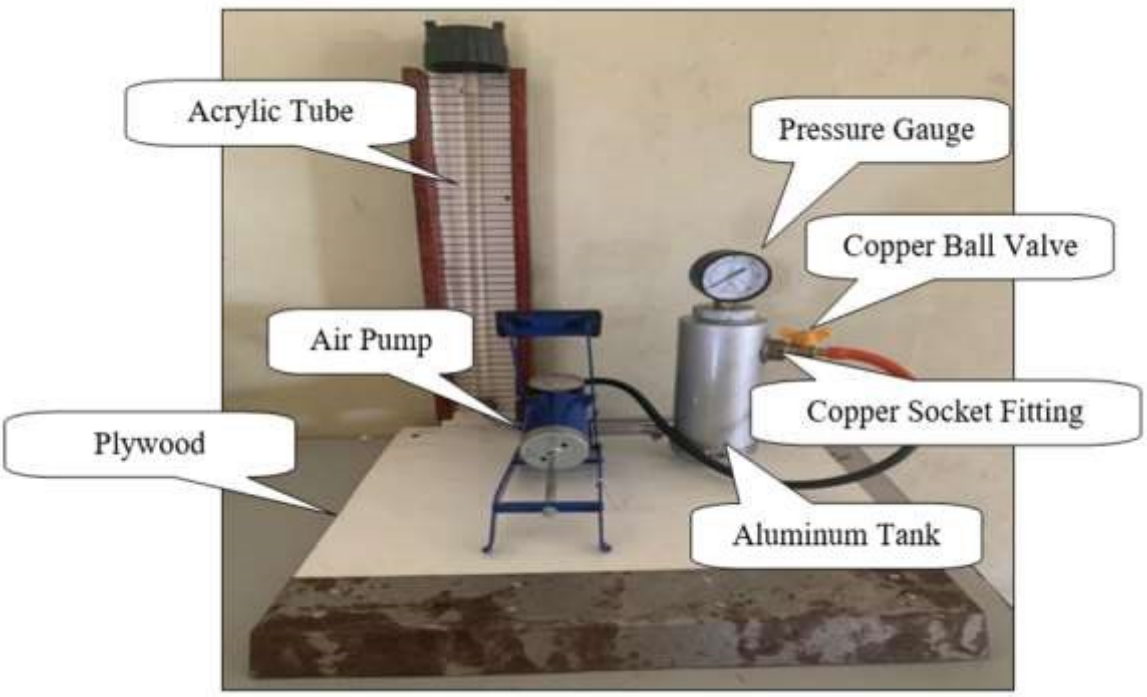

Figure 12. Boyle's Law Apparatus Components

3.5 Components

- Pressure Gauge: Used to measure the pressure of a gas or liquid in a closed container. Used for air and gas pressure monitoring in compressors, vacuum equipment, and special tank applications.
- Aluminium Tank: Used as a container for oil / air in a certain amount.
- Copper ball valve: Used as a way for air to enter the aluminum tank and serves to lock the air inside the tank so that it does not leak.
- Acrylic Tube: Function as a device to measure oil / water fitted with a 'measuring scale' □ Air Pump: Function to produce air flowing into the tank through a copper ball valve.
- Copper socket fitting: Function for connection between pressure gauge and aluminium tank. □ Plywood: Used to make base of apparatus.

4. Result And Discusion

The process of development and production of apparatus runs as planned. From the analysis done between stainless steel, copper and aluminium alloy, aluminium alloy is selected as the product material and also known as stainless steel. This aluminium alloy can maintain a constant temperature for liquids. It also has a high level of strength and is suitable to be used as a tank capable of maintaining temperature compared to copper and stainless steel. This type of alloy material is also lighter and easier to assemble due to the material being not too hard and not too soft. This coincides with statements from Indra, Darsin & Sumarji (2011) who stated that aluminium is currently widely used in industries around the world. This is because aluminium belongs to the category of light metals that have high strength, corrosion resistance and good electrical conductivity. In addition, aluminium also has good formability and aluminium is lighter than iron. This material is also widely used in the industry for the manufacture of teaching aids for students. This alloy type material also has higher oxidation resistance than stainless steel and copper. This aluminium alloy is also easy to shape and assemble according to the suitability of the material to be done. It has the desired characteristics in producing a product, especially a project to help students in learning. Specification of aluminium alloy as shown in table 1 below:

Table 1: Properties of aluminium alloy

PROPERTY	VALUE	UNITS
Elastic Modulus	2.1×10^{11}	N/mA
Poisson's Ratio	0.28	N/A
Shear Modulus	7.9×10^{10}	N/mA^2
Mass density	7700	Kg/mA^3
Tensile Strength	723825600	N/mA^2
Yield strength	620422000	N/mA^2
Thermal Expansion Coefficient	1.3×10^{-5}	/K
Thermal Expansion Coefficient	50	W/(m-K)

There is a difference in the actual cost compared to the estimated cost of equipment development. However, the difference between the estimated cost and the actual cost is not much different. Other than that, the apparatus can function well and easy to used. However, improvement can also be made to existing apparatus such as using electric air pumps as well as a fine scale at pressure and measurement scale of volume at acrylic tube to facilitate reading taken by its users.

It can be stated here that, teaching aids or laboratory apparatus is not something new in the field of engineering. The development of various equipment has been widely produced in various fields. Similarly, research on the development of teaching aids as well as laboratory equipment. Research on the development of experimental kits for example for science learning has also been conducted by several researchers (Saputri & Dewi, 2014; Preliana, 2015; Budiyanto, 2015; Yulianti, Zulkardi & Siroj, 2010; Hasbi & Gunawan, 2015) to produces feasible experiment kit which has a positive effect on learning outcomes.

The results of the testing conducted with the students using this apparatus show that it gives a positive impact and understanding on the academic development and can attracts the students. The use of teaching aids is also supported by Zidny et al (2019) based on the results of studies conducted with limited scale, it can 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.

Not only that, the development and use of learning tools is also supported by studies and statements Makahinda (2019) where he stated development of learning tools and media with performance appraisal and technological application

approaches to learning Thermodynamics is very helpful in involving students in the learning process of observing phenomena of Thermodynamic law, understanding concepts and being able to find the physical principles of Thermodynamic law. This is evidenced from her results of the study where, the result of product development was at 81% -100% feasibility level, therefore the thermodynamic learning tools and media are very feasible to use (Makahinda, 2019).

5. Conclusion

With the result of this 'Boyle's Law Apparatus' project, it is hoped that it will be able to help students in strengthening the concept and basics of Boyles Law in the title of Perfect Gas. This apparatus can also be used as a tool that can be used in practice in the Thermodynamics laboratory in order to support and provide more understanding to students because it can be learned 'hands on'. Apart from that, this equipment can facilitate the lecture delivery process conducted by the lecturers who teach will in turn be able to increase the interest of students to deepen the Thermodynamics course, especially in the topic of Perfect Gas.

Rujukan

Alam, F., Dilla, E., Subic, A., & Tu, J. (2007). A three - step teaching and learning method in laboratory experiments for a thermal fluid course. World Transactions of Engineering and Technology Education. 6 (1), pp. 13-18.

Alam, F., Tang, H., & Tu, J. (2004). The development of an integrated experimental and computational teaching and learning tool for thermal fluid science, World Transactions on Engineering and Technology Education, 3 (2), pp. 249-252.

Budiyanto, A. (2015), 'Pengembangan Alat Peraga Sederhana Struktur dan Organ Dalam Ikan untuk Mempermudah Pembelajaran pada Praktikum Ikhtiologi Perikanan', Jurnal Kelautan, vol. 8, no. 2, pp. 83-88.

Chowdhury, H., Alam, F., & Mustary, I. (2019). Development of an innovatiove technique for teaching and learning of laboratory experiments for engineering courses. Energy Procedia, 160(2018), 806–811. https://doi.org/10.1016/j.egypro.2019.02.154.

Chowdhury, M. S., & Shahabuddin, A. M. (2007). Self-Efficacy, Motivation and Their Relationship to Academic Performance of Bangladesh College Students. College Quarterly, 10(1), 1-9.

Dukhan, N. (2015). On the worldwide engineering students' meager performance in thermodynamics. QScience Proceedings, 2015(4), 17. https://doi.org/10.5339/qproc.2015.wcee2014.17.

Feisel, L. D., & Rosa, A. J. (2005). The Role of the Laboratory in Undergraduate Engineering Education, Journal of Engineering Education, 94, pp. 121-130.

Hasbi, M, A., & Gunawan, K. (2015). 'Pengembangan Alat Peraga Listrik Dinamis (APLD) Berbasis Inkuiri untuk Meningkatkan Penguasaan Konsep Siswa', Jurnal Penelitian Pendidikan IPA, vol. 1, no. 1, pp. 57-67.

Hashim, A., Yaakub, R., & Ahmad, M. Z. (2003). "Pedagogi: Strategi dan Teknik Mengajar dengan Berkesan." Pahang: PTS Publications & Distributors Sdn. Bhd.

Indra, M., Darsin, M., & Sumarji. (2011). Sifat Mekanik dan Struktur Mikro Alumunium AA1100 Hasil Pengelasan Friction Stir Welding dengan Fariasi Feed Rate. 15–22.

Kalyani, D., & Rajasekaran, K. (2018). Innovative Teaching and Learning. Journal of Applied and Advanced Research, 3(S1), 23. https://doi.org/10.21839/jaar.2018.v3is1.162.

Le Maréchal, J. F., & Bilani, R. El. (2008). Teaching and learning chemical thermodynamics in school. International Journal of Thermodynamics, 11(2), 91–99. https://doi.org/10.5541/ijot.1034000216.

Makahinda, T. (2019). Application of Performance Assessment and Technology-Applied Approach of Thermodynamics Learning on High School Students. 4(10).

Marisda, D. H. (2014). Pengembangan Modul Fisika Kesehatan Materi Getaran, Gelombang dan Bunyi Melalui Model Pembelajaran Langsung di SMK Kesehatan Terpadu Mega Rezky Makassar. Jurnal Pendidikan Fisika. 4(3): 268-275.

Nasution. (2005). Psikologi Pengajaran Nasional. Bandung: Remaja Rosda Karya.

Preliana, E. (2015). 'Pengembangan Alat Peraga Sains Fisika Berbasis Lingkungan untuk Materi Listrik Statis pada Siswa Kelas IX SMP Negeri 3 Pleret', JRKPF, vol. 2, no.1, pp. 6-11.

Rashidi & Razak, A. (1996). "Pengajaran dalam Bilik Darjah: Kaedah dan Strategi."Selangor: Penerbit Masa Enterprise.

Sang, M. S. (2000). "Ilmu Pendidikan Untuk KPLI." Kuala Lumpur: Kumpulan Budiman Sdn. Bhd.

Saputri, V. A. C., & Dewi, N. R. (2014). 'Pengembangan Alat Peraga Sederhana Eye Lens Tema Mata Kelas Viii Untuk Menumbuhkan Keterampilan Peserta Didik', Jurnal Pendidikan IPA Indonesia, vol. 3,no. 2, pp. 109-15.

Yulianti, E., Zulkardi., & Siroj, R, A. (2010), 'Pengembangan Alat Peraga Menggunakan Rangkaian Listrik SeriParalel Untuk Mengajarkan Logika Matematika Di Smk Negeri 2 Palembang' Jurnal Pendidikan Matematika, vol 4, no.1, pp. 25-32.

Zidny, R., Fadhilah, G. A., Melda, G. E., Sholihah, I. I., Widiastuti, N. L., Haerunnisa, N., & El Islami, R. A. Z. (2019). Simple and Low-Cost Chemical Experiment Kits to Observe the Concept of Gas Laws. Jurnal Penelitian Dan Pembelajaran IPA, 5(1), 16. https://doi.org/10.30870/jppi.v5i1.3917.