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Learning Ohm's Law through Electric Puzzle Media

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Abstrack

Electrical circuit components or electronic circuits can be connected with series and parallel circuits. The arrangement of the circuit can affect the desired lamp characteristics. This study aims to measure the magnitude of resistance in an electrical circuit, analyze the flame of a series and parallel resistance, explore the relationship between voltage (V) with current (I) in series and parallel circuits. The method research used quantitative methods based on the problem-solving laboratory. The laboratory equipment used consists of a battery, incandescent lamps, resistors, stacking and zinc puzzles, multimeters, jumper cables. The laboratory equipment assembled and measured the intensity of the light produced using the physics toolbox application on a handphone. The data has obtained, then presented in a table and calculated using a formula, and analyzed the uncertainty in its measurement. The result showed the intensity of light in a series of different magnitude, the power of the light was more significant in lamp one, and in lamp two, the power was smaller. The intensity of the light in the parallel circuit was the same magnitude. Still, the value of the light intensity in the parallel circuit was smaller than the intensity in the lamps arranged in series. The relationship between voltage (V) and current (I) in both series and parallel circuits was comparable and directly proportional. Thus, the developed series of electric puzzles can adequately explain Ohm's law. Ohm's law learning with electric puzzles can be used in school and learned by students quickly.

Keywords: electric puzzle, problem solving, Ohm's Law

INTRODUCTION

The world of education in the 21st century has many challenges that must be faced, such as competencies needed in the future, negative phenomena that have emerged, and various developments in knowledge and pedagogy so that critical thinking, creative thinking, and communication skills are needed in solving problems (Kemendikbud 2013). One of the efforts to improve education quality is by optimizing the learning process (Rimbawati & Muchlas 2015). Curriculum development is very influential in education because it will impact the quality of the learning implementation process, so it is hoped that Indonesia's quality of education will also be better (Elfachmi 2016).

Physics is a subject closely related to everyday life because physics is one part of science that studies various objects in nature or natural phenomena (Hasbi, Kosim & Gunawan 2015). Physics includes products, aspects, and attitudes (Sari, Gunawan & Harjono 2017).

Electricity has become the main requirement. Almost all daily activities use electrical energy (Sunaryo & Ruliana 2015). One of the discussions is Ohm's Law. George Ohm stated that the value of the electric current flowing through a conductor would be proportional to the value of the voltage

(Hikmawati 2016; Wahyudi 2015; Sedana, As'ari & Tanauma 2015; Saefullah et al. 2018; Giancoli 2001). Ohm's Law has an important role in practical applications of electricity and electronics. Students' difficulties with Ohm's Law begin with a misunderstanding of the different roles played by the two electrical laws that bear the name Ohm (Kipnis 2009). Several studies point to student difficulties in learning electrical circuits, basic electrical concepts, and various ways to overcome them (Cohen, Eylon & Ganiel 1983; Shipstone 1984, McDermott & Shaffer 1992).

An electric device's circuit is grouped into two, namely circuit of series and parallel (Surya 2010). Resistors are used as part of electronic circuits and are one of the most commonly used components. The main characteristics of resistors are their resistance and the electrical power they can deliver (Giancoli 2001; Van 2002). Resistors have almost the same properties as incandescent lamps because they both play inhibitors in a circuit (Warapsari & Saptorini 2015).

The problem that often occurs when an educator in delivering physics concepts is only conveying equations; it does not facilitate students to find a concept independently (Masril, Hidayti & Darvina 2018). The learning process has two elements: methods and media (Kristiana, Nurwahyunani & Sulistya 2016). The learning method is a procedure to help students receive and process information (Astra & Fitri 2017). Meanwhile, learning media can represent information that is less able to be pronounced (Sukroyanti 2016). Combining methods and media will further encourage students to understand the learning content (Karliana, Muliyati & Siahaan 2015).

Problem-solving is a learning method that usually begins with identifying a problem (Risnawaty, Werdhiana & Hatibe 2015). Problem-solving methods lead students to be more active in learning by understanding problems, planning problem solving, executing plans, to evaluating their performance results (Taqwa & Rivaldo 2019). Application of problem-solving models can improve critical thinking skills, foster initiative at work, and internal motivation to learn (Malik, et al. 2019a; Suhendi et al. 2018). The laboratory activities in the problem-solving laboratory model consist of real-world problems, evaluation and idea selection, group predictions, question methods, exploration, measurement, data analysis, and conclusions (Malik et al. 2019b; Sutarno et al. 2017). Puzzles are a learning medium to increase student motivation (Joneska, Astalini & Susanti 2016; Armiati & Pahriah 2013). The benefits of playing puzzles include sharpening the brain, training eye and hand coordination, practicing reasoning, training patience, and knowledge. The jigsaw puzzle game application in learning Ohm's Law is expected to create student interest in learning (Yulianti, Lestari & Yulianto 2010).

Technology and information are currently developing very rapidly. The current trend shows that the majority of students have smartphones to communicate. Smartphones can also be used as learning media (Astutia, Sumarni & Saraswati 2017). Physics Toolbox is an application that can be downloaded and used on a smartphone to measure the intensity of the light in the lamp accurately (Prabowo & Sucahyo 2018; Sari, Yulkifli & Kamus 2015; Pamungkas, Hafiddudin & Rohmah 2015).

Previous research tried to minimize students' misunderstandings regarding electrical. Various methods have been used to improve students' understanding of electrical circuits and ohms law (Prasetyaningrum & Pratama 2019; Mitchell et al. 2018; Setyani et al. 2017). The novelty of this research is to develop an electric puzzle as a learning medium to explain Ohm's Law. Electric puzzles use zinc attached to the puzzle to conduct current. The battery is used as a voltage source and an incandescent lamp as a resistance. The electric puzzle developed uses the Physics Toolbox application on a smartphone to measure light intensity produced by lights in a series and parallel series. The electric puzzle design made facilitates students to carry out laboratory activities and can improve higher-order thinking skills. The electric puzzle developed strengthens previous research. This tool can improve students' ability to analyze and be creative (Saefullah et al. 2018).

The research objective is to develop students' abilities in laboratory-based Problem Solving Laboratory activities using electric puzzles. Students are expected to be able to think actively, creatively, and critically regarding Ohm's Law. This study's results are expected to increase the results, interests, and learning activities of students with a contextual approach and produce innovation in the implementation of physics learning, especially in Ohm's Law.

METHODS

The research method uses an experimental approach based on a problem-solving laboratory. Electric puzzles developed to measure electric current, measure voltage and resistance in electrical circuits, analyze lights in series and parallel resistance and analyze factors that affect resistance. Besides, it explores the relationship between voltage (V) and electric current (I) in series and parallel circuits and determines the value of electric current at different resistances.

Electric puzzles are made from tools that can found in everyday life. The equipment needed consists of 9V batteries (2 pieces), light bulbs (4 pieces), jumper cables (4 pieces), multimeter (2 pieces), enough zinc puzzles. This tool's working principle begins with assembling a practicum tool, then connecting the circuit at the source voltage. Then measure the voltage, current, and light intensity in the lamp. Overall, the steps taken to design and create an Electric Puzzle are shown in FIGURE 1.

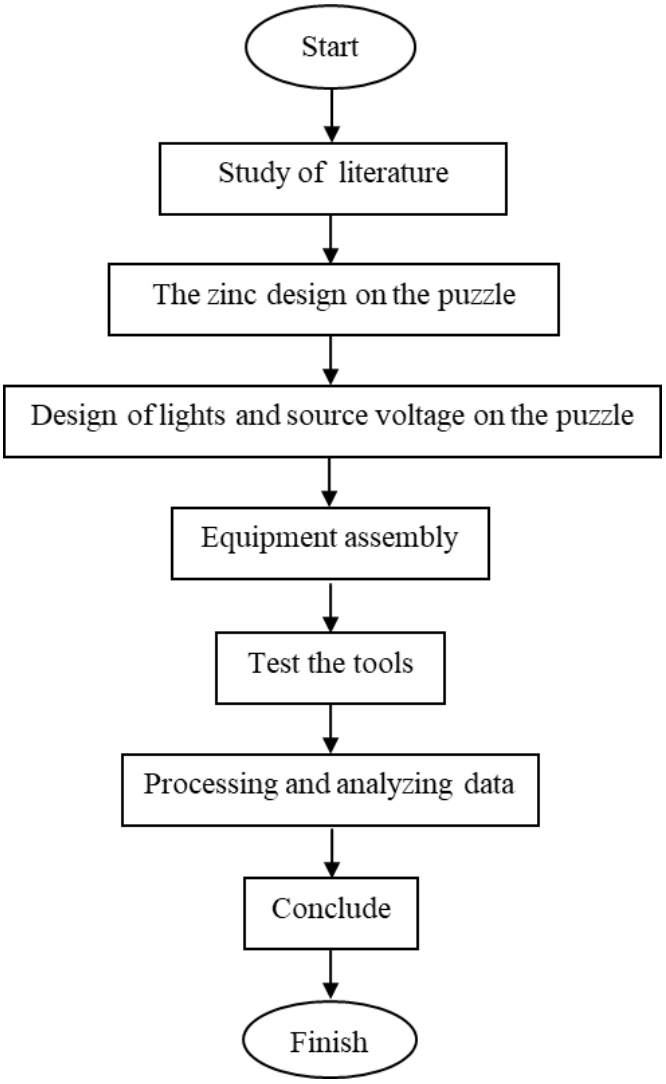

FIGURE 1. Flowchart of Electric Puzzle Making

RESULTS AND DISCUSSION

The electric puzzle that has been made can be used to practice higher-order thinking skills in students. These skills are trained and developed through working on problem solving-based laboratory activity guide sheets. Worksheets guide students to practice their analytical and creative skills (Pamungkas, Hafiddudin & Rohmah 2015).

The design of the Electric Puzzle practicum tool must be able to train higher-order thinking skills. One indicator is the ability to analyze puzzle arrangements for series and parallel circuits so that electric current can flow. The electric puzzle design for laboratory activities related to Ohm's law is shown in FIGURE 2.

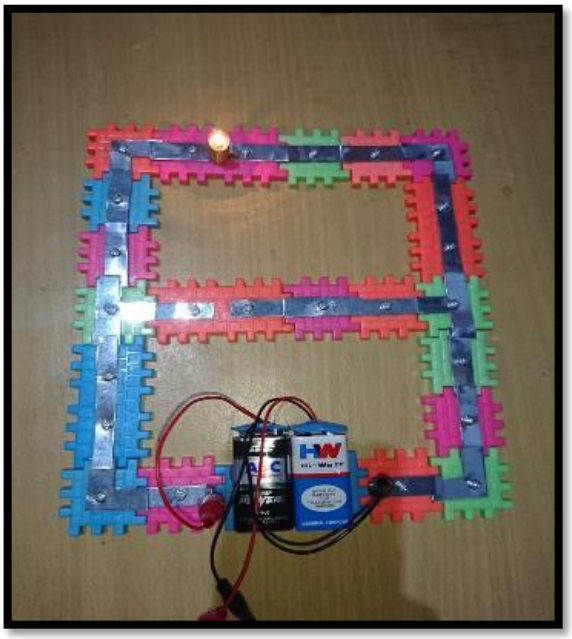

FIGURE 2. Circuit of Electric Puzzle

Experiments were carried out by assembling an electric puzzle and collecting data 20 times. The results of data measurement in a series are shown in TABLE 1.

TABLE 1. Measurement Results on Series Circuit

Experiment	V_s	Voltage (V)		Current (A)		Intensity (lx)	
		V_1	V_2	I_1	I_2	I_1	I_2
1	8.2	2.0	1.8	0.225	0.225	58	39
2	8.2	2.0	1.8	0.225	0.225	58	39
3	8.2	1.8	1.6	0.225	0.220	58	39
4	8.2	1.8	1.6	0.220	0.220	57	39
5	8.2	18	1.6	0.220	0.215	57	38
6	8.2	1.6	1.4	0.215	0.215	56	38
7	8.2	1.6	1.4	0.215	0.215	53	38
8	8.2	1.6	1.4	0.215	0.210	52	37
9	8.2	1.4	1.2	0.210	0.210	50	33
10	8.2	1.4	1.2	0.215	0.210	49	33
11	8.2	2.0	1.8	0.210	0.215	49	30
12	8.2	1.8	1.6	0.225	0.225	57	30
13	8.2	1.8	1.8	0.210	0.215	57	28
14	8.2	1.6	1.6	0.215	0.210	57	38
15	8.2	1.6	1.6	0.220	0.210	56	37
16	8.2	1.8	1.8	0.215	0.210	56	33
17	8.2	1.8	1.4	0.220	0.215	52	33
18	8.2	1.6	1.4	0.210	0.215	50	33
19	8.2	1.6	1.6	0.215	0.220	50	28
20	8.2	1.8	1.6	0.220	0.220	49	28

The voltage source (Vs) used in the series circuit is 8.2 volts. The highest value obtained at V_1 is 2 volts, while the lowest is 1.4 volts. The obtained value continues to decrease as the source of the battery continues to decline. At the V_2 voltage, the highest value obtained is 1.8 volts, while the lowest is 1.2 volts. The value obtained is smaller than V_1. In currents I_1 and I_2, the changes are the same. The highest value obtained is 0.225 Ampere, while the lowest is 0.210 Ampere. The intensity of the light produced in the series is brighter at I_1 than in I_2.

TABLE 2. Measurement Results on Parallel Circuit

Experiment	V_s	Voltage (V)		Current (A)		Intensity (lx)	
		V_1	V_2	I_1	I_2	I_1	I_2
1	15	1	1	0.12	0.18	1	2
2	15	1	1	0.12	0.18	7	7
3	15	1	1	0.12	0.19	5	5
4	15	1	1	0.11	0.18	5	7
5	15	1	1	0.14	0.19	7	5
6	15	1	1	0.13	0.21	7	7
7	15	1	1	0.12	0.18	5	5
8	15	1	1	0.13	0.19	5	7
9	15	1	1	0.11	0.21	7	5
10	15	1	1	0.12	0.18	10	7
11	15	1	1	0.11	0.20	5	7
12	15	1	1	0.12	0.18	7	5
13	15	1	1	0.13	0.18	7	7
14	15	1	1	0.13	0.21	5	7
15	15	1	1	0.13	0.20	7	5
16	15	1	1	0.10	0.21	10	7
17	15	1	1	0.11	0.21	5	5
18	15	1	1	0.13	0.19	7	7
19	15	1	1	0.90	0.19	7	7
20	15	1	1	0.12	0.19	5	5

The voltage source (Vs) used in the parallel circuit is 15 volts. The voltage at V_1 the value obtained is the same as the voltage at V_2, which is 1 Volt. At current I_1, the highest value obtained is 0.14 Volt, and the lowest is 0.90 Volt. At current I_2, the highest value obtained is 0.21 Ampere, while the lowest is 0.18 Ampere. The value obtained is greater at I_2 than I_1. The intensity of the light produced in the parallel circuit is brighter on I_1 than in I_2. The lowest amount of light intensity at I_1 is 10 lx while at I_2 is 7 lx. The highest value of light intensity at I_1 is 1 lx while at I_2 is 2 lx.

Data processing results and calculations of voltage, electric current and light intensity in series and parallel circuits are associated with Ohm's law. The calculation results are shown in TABLE 3.

TABLE 3. Processing and Calculation of Experimental Data

Circuit	*I* (A)	*Eror (%)*	*V* (V)	*Eror (%)*	*R* (Ω)	*Eror (%)*	*I* (lux)	*Eror (%)*
Seri	0.21 ± 0.015	7.1	1.72 ± 0.03	2.29	8.19 ± 0.60	7.36	(5.405 ± 0.0025) 10^1	0.04
	0.20 ± 0.01	6.6	1.56 ± 0.04	2.72	7.80 ± 0.43	5.61	(3.4 ± 0.7) 10^1	21
Parallel	(1.6 ± 0.3) 10^{-1}	24	1.0 ± 0.1	10	8.1 ± 1.3	16	6.2 ± 0.43	7.07
	(1,93 ± 0.27) 10^{-1}	1.3	1.0 ± 0.1	10	5.2 ± 0.7	14	5.95 ± 0.30	5.09

The data obtained shows the variation in the source voltage and the type of circuit used. The results used to determine the relationship between voltage and electric current in series and parallel circuits. The most incredible light intensity occurs when the arranged in series.

Based on the data in Table 1, a graph of the relationship between voltage (V) and electric current (I) can make in a series circuit. The relationship graph is shown in FIGURE 2.

The graph in Figure 3 shows that the chart tends to increase, it shows that the relationship between voltage (V) and current (I) is proportional. If the voltage (V) is greater, the current (I) will also be more significant. The results accord with the Ohms law, which shows that the voltage (V) is proportional to the current (I). The relationship between voltage and current is shown by mathematical:

$$V = R\,I \tag{1}$$

Mathematically it can be written:

$$V \approx I \tag{2}$$

The gradient value (m) = 0.9017 in the graph above is the value

$$\frac{1}{R}\ so\ R = \frac{V}{I} \tag{3}$$

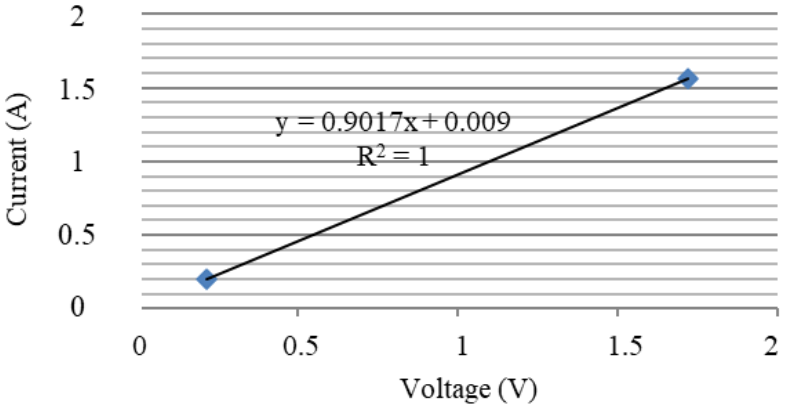

FIGURE 3. The Relationship of Voltage (V) and Electric Current (I) in a Series Circuit

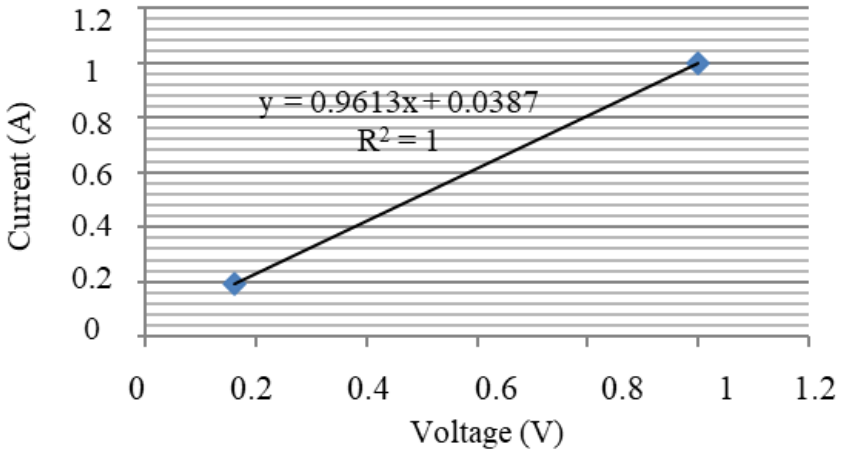

FIGURE 4. The Relationship of Voltage (V) and Current (I) in a Parallel Circuit

The graph on figure 4 shows that the chart tends to increase, it shows that the relationship between voltage (V) and current (I) is proportional, if the voltage (V) is greater, the current (I) will also be more significant. The results accord with the Ohms law, which shows that the voltage (V) is proportional to the square current (I). The gradient value (m) in the graph above is 0.9613. These results show compatibility with the graph in FIGURE 3.

Based on the experiments that have been carried out in series and parallel circuits, it is found that the relationship between voltage (V) and current (I) is always proportional. The results obtained are by Ohm's law. But there are differences in each circuit. In a series, the value of the electric current in each lamp is always the same. Even though it uses a different voltage on each light. Whereas in a parallel circuit the voltage is still the same in each lamp with the electric current produced is different for each lamp. Research on misconceptions of current and voltage has revealed several conceptions (Koponen & Huttunen 2013; Engelhardt & Beichner 2004; Lee & Law 2001). With this result, it can minimize the conception of the difference between the concepts of electric current and voltage.

The light intensity in a series of different magnitudes, the light intensity in lamp 1 is greater than that of lamp 2. This result is because the resistance on each lamp is extra so that the intensity is different. The light intensity in parallel circuits is the same. The light intensity of lamps in parallel circuits is less than the power of lamps connected in series. This result is because, in parallel circuits, the value of electric current is divided while in series circuits are not. The amount of light intensity in series and parallel circuits depends on the electric current flowing. The relationship between electric current and light intensity is shown in FIGURE 5.

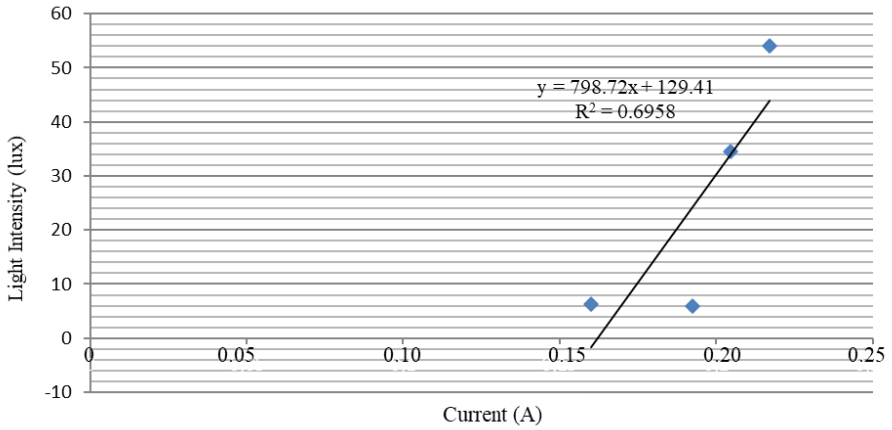

FIGURE 5. Relation of Electric Current (I) to Light Intensity (I)

The graph in FIGURE 5 shows the effect of electric current (I) on light intensity (I) in series and parallel circuits. The relationship is the same, indicating that the light intensity (I) is proportional to the current strength (I).

The data obtained from the electric puzzle and the data obtained using ordinary electrical circuits such as KITs get the same result that the current (I) is proportional to the voltage (V). This electric puzzle tool can be used to provide an understanding of Ohm's law more excitingly.

This study has limitations in the use of source voltage and some puzzles. Electric puzzles use batteries so that over time the voltage value decreases. Further research is better to use a power supply so that the source voltage is more constant. The voltage used in a parallel circuit is different from a series circuit. If the series's voltage is the same as in the parallel circuit, the lamp attached to the circuit will break.

Conversely, if the parallel circuit's voltage is the same as in series, then the course's light will not turn on. The number of puzzles in the circuit, the series, and parallel is adjusted according to the circuit type. Puzzles in of the circuit the series are not branched, whereas parallels are made branched. There are more puzzles in a parallel circuit than in a series.

CONCLUSION

The results showed the relationship between voltage (V) and current strength (I) is directly proportional. If the voltage is enlarged, the resulting current will also be large and vice versa. These results apply to parallel circuits and series circuits. The light intensity in the lamps connected in series is brighter than in the parallel circuit. In a parallel circuit, the sizeable electric current that flows will be divided, but the voltage value is the same at each point. The result is that the two lights are equally bright. As for the series circuit, the strong current value for each lamp is always the same. The voltage is different for each lamp. Only lights close to a positive voltage source have a very bright lamp, while the second lamp has dim lights. Electric puzzles are a learning medium that can train and improve reasoning, motor skills, patience, and creativity. Thus, it is expected to create student interest in learning.

REFERENCES

Armiati, SE & Pahriah 2013, 'Pengaruh model somatic auditory visualizationi intelectualy (savi)', dengan media puzzle terhadap aktivitas dan pemahaman konsep siswa pada materi hidrokarbon" Jurnal Ilmiah Pendidikan Kimia, vol. 3, no. 2, pp. 302–08.

Astra, IM & Fitri, UR 2017, 'Integrated lecture tools to improve student competencies to develop physical learning media design', Jurnal Penelitian & Pengembangan Pendidikan Fisika, vol. 3, no. 1, p. 79, doi: 10.21009/1.03111.

Astutia, IAD, Sumarni, RA & Saraswati, DL 2017, 'Pengembangan media pembelajaran fisika mobile learning berbasis android', Jurnal Penelitian & Pengembangan Pendidikan Fisika, vol. 3, no. 1, p. 57, doi: http://doi.org/10.21009/1.

Cohen, R, Eylon, B & Ganiel, B 1983, 'Potensial difference and current in simple electric: A study of student's concepts', American Journal of Physics, vol. 51, no. 5, pp. 407-12, doi: 10.1119/1.13226.

Elfachmi, AK 2016, 'Pengantar Pendidikan', Jakarta: Erlangga.

Engelhardt, PV & Beichner RJ 2004, 'Students' understanding of direct current resistive electrical circuits', American Journal of Physics, vol. 72, no. 1, pp. 98-115, doi: 10.1119/1.1614813.

Giancoli, DC 2001, 'Fisika Jilid I. 5 ed', Jakarta: Erlangga.

Hasbi, MA, Kosim & Gunawan 2015, 'Pengembangan alat peraga listrik dinamis (apld) berbasis inkuiri untuk meningkatkan penguasaan konsep siswa', Jurnal Penelitian Pendidikan IPA (JPPIPA), vol. 1, no. 1, pp. 57-67.

Hikmawati 2016, 'Lembar kerja siswa berbasis saintifik pada konsep hukum ohm untuk pembelajaran fisika di sekolah menengah atas', J. Pijar MIPA, vol. 9, no. 1, pp. 51-4.

Joneska, A, Astalini & Susanti, N 2016, 'Perbandingan hasil belajar fisika menggunakan strategi pembelajaran crossword puzzle dan index card match pada materi cahaya kelas viii smp negeri 3 batanghari', Jurnal EduFisika, vol. 1, no. 1, pp. 28-31, doi: 10.1097/00004045-198603000-00008.

Karliana, F, Muliyati, D & Siahaan ZB 2015, 'Pengembangan naskah drama fisika sebagai media pembelajaran fisika sma berbasis joyful learning', Jurnal Penelitian & Pengembangan Pendidikan Fisika, vol. 01, no. 2, pp. 92-102, doi: 10.21009/1.01215.

Kemendikbud 2013, 'Materi Pelatihan Guru: Implementasi Kurikulum 2013 Smp/Mts Ilmu Pengetahuan Alam', Jakarta: Badan Pengembangan Sumber Daya Manusia Pendidikan dan Kebudayaan dan Penjaminan Mutu Pendidikan.

Kipnis, N 2009, 'A law of physics in the classroom: The case of ohm's law', Sci &Educ, vol. 18, no. 1, pp. 349-82, doi 10.1007/s11191-008-9142-x.

Kristiana, IA, Nurwahyunani, ER & Sulistya, D 2016, 'Influence of teams games tournament learning model using puzzle media on students' activity and cognitive', Bioma, vol. 6, no. 2, pp. 78-92.

Koponen, IT & Huttunen, K 2013, 'Concept development in learning physics: The case of electric current and voltage revisited', Science & Education, vol. 22, no. 9, pp. 2227-254, doi:10.1007/s11191-012-9508-y.

Lee, Y & Law, N 2001, 'Explorations in promoting conceptual change in electrical concept via ontological category shift', International Journal of Science Education, vol. 23, no. 2, pp. 111-49, doi: 10.1080/09500690119851.

Malik, A, Novita, Y & Nuryantini, AY 2019a, 'Enhancing critical thinking skills of students related to temperature and heat topics through problem solving-laboratory model', Jurnal Penelitian & Pengembangan Pendidikan Fisika, vol. 5, no. 1, pp. 9-20, doi.org/10.21009/1.05102.

Malik, A, Yuningtias, UA, Mulhayatiah, D, Chusni, MM, Sutarno, S, Ismail, A & Hermita, N 2019b, 'Enhancing problem-solving skills of students through problem solving laboratory model related to dynamic fluid', Journal of Physics: Conference Series, vol. 1157, no. 032010, pp.1-6, doi: 10.1088/1742-6596/1157/3/032010.

McDermott, LC & Shaffer, PS 1994, 'Research as a guide for curriculum development: An example from introductory electricity. Part I: Investigation of students' understanding', American Journal of Physics, vol. 60, no. 11, pp. 994–1003, doi: 10.1119/1.17003.

Mitchell B, Ekey R, McCullough R & Reitz W 2018, 'A fan-tastic quantitative exploration of Ohm's law', The Physics Teacher, vol. 56, no. 2, pp. 75-8, doi: 10.1119/1.5021431.

Masril, Hidayti & Darvina, Y 2018, 'Penerapan discovery learning berbantuan virtual laboratory untuk meningkatkan kompetensi fisika siswa sma', Jurnal Penelitian Pendidikan IPA, vol. 5, no. 1, pp. 18-26, doi: 10.29303/jppipa.v5i1.160.

Pamungkas, M, Hafiddudin & Rohmah, YS 2015, 'Perancangan dan realisasi alat pengukur intensitas cahaya', ELKOMIKA: Jurnal Teknik Energi Elektrik, Teknik Telekomunikasi, & Teknik Elektronika, vol. 3, no. 2, p. 120, doi: 10.26760/elkomika.v3i2.120.

Prabowo, FL & Sucahyo, I 2018, 'Pengembangan media hukum melde berbasis aplikasi physics toolbox sensor suite pada materi gelombang stasioner', Jurnal Inovasi Pendidikan Fisika, vol. 07, no. 02, pp. 165-70.

Prasetyaningrum I & Pratama H 2019, 'Student conception of Ohm's law', Journal of Physics: Conference Series, vol. 1321, no. 022028, pp. 1-6, doi:10.1088/1742-6596/1321/2/022028.

Rimbawati, N & Muchlas 2015, 'Pengembangan model pembelajaran adaptive blended learning untuk berbagai jenis gaya belajar siswa menengah atas pada pokok bahasan listrik statis', Jurnal Penelitian & Pengembangan Pendidikan Fisika, vol. 1, no. 2, pp. 1-6, doi: 10.21009/1.01201.

Risnawaty, Werdhiana, IK & Hatibe, HA 2015, 'Peningkatan hasil belajar ipa fisika dengan menggunakan model pembelajaran problem solving pada siswa kelas vii smp negeri 18 palu', JPFT (Jurnal Pendidikan Fisika Tadulako Online), vol. 3, no. 3, pp. 13–7, doi: 10.22487/j25805924.2015.v3.i3.5130.

Saefullah, Fakhturrokhman, M, Oktarisa, Y, Arsy, RD, Rosdiana, H, Gustiono, V, & Indriyanto 2018, 'Rancang bangun alat praktikum hukum ohm untuk memfasilitasi kemampuan berfikir tingkat tinggi (higher order thinking skills)', Gravity: Jurnal Ilmiah Penelitian dan Pembelajaran Fisika, vol. 4, no. 2, pp. 81-90, doi: 10.30870/gravity.v4i2.4035.

Sari, MB, Yulkifli, Y & Kamus, Z 2015, 'Sistem pengukuran intensitas dan durasi penyinaran matahari realtime pc berbasis ldr dan motor stepper', Jurnal Otomasi Kontrol dan Instrumentasi, vol. 7, no. 1, p. 37, doi: 10.5614/joki.2015.7.1.5.

Sari, PI, Gunawan, G & Harjono, A 2017, 'Penggunaan discovery learning berbantuan laboratorium virtual pada penguasaan konsep fisika siswa', Jurnal Pendidikan Fisika dan Teknologi, vol. 2, no. 4, pp. 176-82.

Sedana, D, As'ari & Tanauma, A 2015, 'Pemetaan akuifer air tanah di jalan ringroad denganmenggunakan metode geolistrik tahanan jenis', Jurnal Ilmiah Sains, vol. 15, no. 2, pp. 33-7.

Setyani ND, Suparmi, Sarwanto & Handika 2017, 'Students conception and perception of simple electrical circuit', Journal of Physics: Conference Series, vol. 909, no. 012051, pp. 1-11, doi :10.1088/1742-6596/909/1/012051.

Shipstone, DM 1984, 'A study of children's understanding of electricity in simple DC circuits', European Journal Science Education, vol. 6, no. 2, pp. 185–98, doi: 10.1080/0140528840060208.

Suhendi HY, Lunggari, TDC, Utari, S & Hasanah, L 2018, 'Profil kemampuan berpikir kritis dan peningkatan prestasi belajar siswa sma melalui penerapan strategiproblem solving dengan reading infusion', Gravity : Jurnal Ilmiah Penelitian dan Pembelajaran Fisika, vol. 4, no. 1, doi: 10.30870/gravity.v4i1.3120.

Sukroyanti, BA 2016, 'Pengaruh penggunaan pocket book siswa dengan teknik evaluasi media puzzle ceria terhadap sikap ilmiah siswa', Lensa : Jurnal Kependidikan Fisika, vol. 4, no. 2, pp. 46-50, doi: 10.33394/j-lkf.v4i2.82.

Sunaryo, RB & Ruliana, SK 2015, 'Kajian fisis energi terbarukan panel surya melalui eksperimen sederhana untuk siswa sma', Jurnal Penelitian & Pengembangan Pendidikan Fisika, vol. 1, no. 2, pp. 81-8, doi: 10.21009/1.01213.

Surya, Y 2010, 'Listrik dan Magnet', Tanggerang: PT. Kandel.

Sutarno, Setiawan, A, Suhandi, A, Kaniawati, I &Putri, DH 2017, 'Keterampilan pemecahan masalah mahasiswa dalam pembelajaran bandul fisis menggunakan model problem solving virtual laboratory', Jurnal Pendidikan Fisika dan Teknologi, vol. 3, no. 2, p. 164, doi: 10.29303/jpft.v3i2.396.

Taqwa, MRA & Rivaldo, L 2019, 'Pembelajaran problem solving terintegrasi phet: membangun pemahaman konsep listrik dinamis', Kwangsan: Jurnal Teknologi Pendidikan, vol. 7, no. 1, pp. 45-56, doi: 10.31800/jtp.kw.v7n1.p45--56.

Van, H 2002, 'Instalasi Arus Listrik', Jakarta: Trimarta.

Wahyudi 2015, 'Analisis hasil belajar mahasiswa pada pokok bahasan hukum ohm dan kirchoff dalam matakuliah elektronika dasar I', Jurnal Pendidikan Fisika dan Teknologi, vol. 1, no. 2, pp. 129-35, doi: 10.29303/jpft.v1i2.248.

Warapsari, DA & Saptorini 2015, 'Pengembangan contextual puzzle dalam pembelajaran ipa berbasis proyek tema pencemaran dan dampaknya bagi makhluk hidup', USEJ - Unnes Science Education Journal, vol. 4, no. 1, pp. 807-14, doi: 10.15294/usej.v4i1.5014.

Yulianti, D, Lestari, M & Yulianto, A 2010, 'Penerapan Jigsaw puzzle competition dalam pembelajaran kontekstual untuk meningkatkan minat dan hasil belajar fisika siswa smp', Jurnal Pendidikan Fisika Indonesia, vol. 6, no. 2, pp. 84–9, doi: 10.15294/jpfi.v6i2.1118.