Making Supercapacitors as Teaching Materials

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Al-Ishlah: Jurnal Pendidikan
Vol.14, 4 (December, 2022), pp. 5723-5732
ISSN: 2087-9490 EISSN: 2597-940X, DOI: 10.35445/alishlah.v14i4.1813

Making Supercapacitors as Teaching Materials for Science Lab Work in High Schools for Supporting the Development of Renewable Energy

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ARTICLE INFO

Keywords:

Supercapacitor;
potentiostat;
lab work;
energy storage

Article history:

Received 2021-10-24
Revised 2022-02-28
Accepted 2022-12-05

ABSTRACT

This paper reports the results of the development of science lab work teaching materials that focus on the development of renewable energy, especially energy storage devices. The energy storage device discussed was the supercapacitor, including the tools and materials used the manufacturing method and the theory underlying the supercapacitor. The method applied to the development of science lab work teaching materials consists of activity design, subject, data collection and data analysis. The results of data analysis show that the development of labwork teaching materials for senior high schools is suitable for use by educators in science learning based on the assessment of the lecturers / teachers resulting in an assessment with a 95% feasibility percentage (very feasible). Student responses showed that the average number of 86.8% included in the category of very interested. It can be said that the students are very interested in learning to use the material presented. Several recommendations can be given, namely that more plenty and diverse teaching materials are needed in order to make students of high schools can understand the government programs that are being launched and it is necessary to conduct research by teachers and students so that schools can produce students who have capability to enter competition in larger events.

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1. INTRODUCTION

Education has become a basic need to improve and develop the potential of human resources. Education is an interaction process that encourages the learning process. Through education, it is expected to be able to develop the potential of students so that they can become more qualified human resources. In law number 20 of 2003 concerning the national education system, it is stated that the curriculum is a set of plans and arrangements regarding the objectives, content and learning materials as well as the methods used as guidelines for the implementation of learning activities to achieve certain educational goals. (Zhafirah et al., 2020). Schools as one of the basic elements of education have obligations and responsibilities to produce quality human resources. The progress and decline of a country's economic and technological system is also influenced by the state of its human resources, which is motivated by the human ability to channel interests and talents that can be further developed from the middle level. (Manikowati & Iskandar, 2018)

Chemistry and physics are basic sciences taught in schools and also play an important role in the formation of human resources (Susilo et al., 2018). Conditions of learning in schools, especially high school, especially in the exact field, are not always balanced with labwork in the laboratory (Rahman et al., 2015). The absence of facilities and infrastructure to support the implementation of labwork is the basic reason that often arises for the low interest and talent in exact sciences, not only in Indonesia but also other countries (Bukhari et al., 2019). In addition, the lack of ideas and the lack of simple tool designs are also one of the causes of the failure of the learning program followed by labwork in the laboratory.

The laboratory work can be one of the drivers of the growth of the will, desire and awareness of secondary students that science is the basis of current technological developments (Agustini et al., 2020). The development of simple ideas and equipment carried out in schools will be a driving force to further develop students' abilities in their respective fields of specialization. Some ideas that can be developed are energy conservation and sustainable energy which is one of the pillars in the sustainability development goals (SDGs) proclaimed by many countries in the world. (Yuniarti et al., 2011).

Energy storage technology is one of the research topics developed at the Faculty of Mathematics and Natural Sciences related to the development of renewable energy and sustainable energy. (Puspadi et al., 2016) Several prototypes and patents have been generated from the research activities carried out so that they can be used to support these activities (Syarif, 2014). The basic idea of making a supercapacitor is specifically to make local content, namely conductive charcoal binchotan. Binchotan carbon and its application to supercapacitors are described in patent document IDP000046138.

This research topic can be used in teaching and labwork for chemistry and physics subjects. This socialization is felt necessary so that students can be technology literate. In addition, there is awareness in the community to be able to participate in the energy conservation movement. Energy storage technology is a form of energy conservation movement. The storage technology in question is energy storage based on electrochemical work, such as battery fuel cells, and supercapacitors. (Syarif & Prasagi, 2016).

The activity of developing practical teaching materials for energy storage devices discussed is supercapacitor with a discussion covering the tools and materials used, manufacturing methods and the theory underlying the supercapacitor. The two halves of the supercapacitor electrode are made of conductive charcoal, barrier and electrolyte of NaCl in PVA glue. Supercapacitor practical teaching materials are prepared to facilitate understanding of the manufacture and theoretical of supercapacitors. Evaluation and implementation activities are interactive by utilizing student involvement in the process as is also applied to every labwork implementation.

2. METHODS

Activity plan

The development of practical teaching materials is carried out using the Analysis, Design, Development, Implimentation, Evaluation (ADDIE) framework as also reported by other authors. (Cahyadi, 2019). The stages in ADDIE consist of (1) the analysis stage which includes the implementation of needs analysis, problem identification and formulating the objectives of the labwork material; (2) the design stage in the form of formulating general goals by classifying students into several types, selecting student activities, selecting media, and planning the objectives of the assessment process, learning activities and learning content, learning strategies used to achieve goals, including the choice of a combination of methods and media the most relevant for designing science labwork teaching materials; (3) the development stage includes preparing materials for students and teachers in accordance with the product specifications being developed; (4) implementation by applying the designs that have been made in schools by first preparing the role or function of each component; (5) evaluate the series of activities that have been carried out.

Subject

The subjects of the activity were teachers and high school students with a total of 30 respondents with data collection instruments in the form of (a) validation sheets from media, material, and language experts to get corrections, criticisms and suggestions for the guided inquiry-based physics labwork module that researchers design on the subject; (b) the questionnaire sheet is used as a tool to see the results of student responses to practical teaching materials in high school.

Data collection

Data collection was carried out on the evaluation and implementation of the development of science labwork teaching materials. Data was collected using (1) assessment sheets and (2) response questionnaires. The assessment sheet is used to obtain input in the form of criticism, suggestions, and responses to the developed teaching materials. To determine the validity of the teaching materials and media prepared. Assessment sheets are given to follow lecturers and teachers. The assessor provides an assessment of the teaching materials by ticking the appropriate rows and columns, writing revision points if there are deficiencies in the suggestions section or can write directly on the teaching material script. The assessment of teaching materials is carried out by two assessors, namely lecturers and teachers in the same field of science. The assessment sheet is in the form of practical material values. The validator's assessment of the labwork material consists of 4 categories, namely invalid (1), quite valid (2), valid (3), and very valid (4). Questionnaires were used to obtain information related to students' opinions / responses to teaching materials consisting of (1) not interested, (2) less interested, (3) interested, (4) very interested.

Data Analysis

Data analysis in the form of quantitative descriptive data to get the average and percentage. The data analysis technique for assessing student worksheets is as follows: the assessment is descriptive qualitative in the form of input suggestions and comments, while the data used in the science labwork material is quantitative data with reference to four assessment criteria: score 1, if the assessment is very poor/very unsuitable (not very good). valid); score 2, if the assessment is not good / less appropriate (less valid); score 3, if the assessment is good/appropriate (valid); and a score of 4, if the assessment is very good/very appropriate (very valid).

The data obtained with the data collection instrument were analyzed using analytical techniques and percentages according to a predetermined formula. Calculate the average score of each aspect assessed by the equation:

$$\overline{X} = \frac{\sum X}{N} \qquad (1)$$

Where X = the average score of the assessment; X = Total scores obtained by experts and N = Number of questions. To change the average score obtained into qualitative data. Student response data was obtained from the results of filling out the student response questionnaire sheet. The assessment scores used are: (1) not interested, (2) less interested, (3) interested, (4) very interested. Furthermore, the data obtained with the data collection instrument were analyzed using analytical techniques and percentages according to a predetermined formula:

$$P = \frac{\sum_i^n x_i}{\sum_i^n y_i} \qquad (2)$$

Where xi is the number of evaluators' answers for the i-th assessment element; yi is the maximum number of values for the i-th aspect; P = percentage of overall assessment and n = number of assessment elements. The calculated P value will show the student's interest criteria. If the P value is 81.25 < x 100 then the criteria are "very interested"; P value 62.50 < x 81.25, "interested" criteria; P value 43.75 < x 62.50, the criteria "less interested"; and P value 25.00 < x 43.75 "not interested".

Evaluation of supercapacitor teaching materials and their relationship to labwork in schools is aimed at teachers and students from grade 12. The topics of discussion when evaluating are (1) providing an understanding of supercapacitors and their relation to labwork in schools, (2) providing practical instructions about teaching materials for science labwork, and (3) providing an overview of teaching materials for science labwork delivered to induce students' interest in the given topic.

3. FINDINGS AND DISCUSSION

Data collection was carried out at one high school. Interviews to schools were conducted beforehand to see the situation and condition of the school and to consult with science teachers, especially chemistry. The product is teaching material in the form of science labwork the form of printed sheets used in science learning at school. The development of science labwork teaching materials uses the ADDIE model with the stages of development research consisting of analysis, design, development, implementation and evaluation.

Analysis

Based on observations, it can be said that some teachers and students are not fully familiar with energy storage devices and the development of renewable energy. Energy storage devices that are known everyday are batteries. Supercapacitors and fuel cells are not known at all. The current era of energy conservation requires that future generations such as high school students understand the concept of energy storage. Based on these observations, the science labwork teaching materials with the concept of energy storage and renewable energy.

Table 1. The results of the assessment by lecturers / teachers for the material and aspects

Elements of assessment	Evaluator 1 score	Evaluator 2 score	Average	score of average	% score	Eligibility
1	4	4	4	3.8	95%	Sangat layak
2	4	4	4			
3	3	4	3.5			
4	4	3	3.5			
5	4	4	4			
6	3	4	3.5			
7	4	4	4			
8	4	3	3.5			
9	4	4	4			
10	4	4	4			

Design

At the design stage, two activities were carried out, namely compiling assessment instruments for the development of teaching materials and arranging systematics of teaching materials and systematics of labwork materials.

The assessment instrument used is in the form of a feasibility assessment sheet for labwork material by fellow lecturers/teachers; assessment sheets by media experts and student response questionnaires. The results of the design phase of the labwork material assessment instrument consist of (a) the feasibility assessment sheet for labwork material and media conducted by 2 lecturers / teachers. This assessment instrument is based on the feasibility aspect to determine the validity of the material developed. This labwork material feasibility assessment sheet is prepared with 4 alternative answer choices, namely very valid, valid, quite valid and invalid; (b) student response questionnaire sheet to assess student interest in the developed module. This response questionnaire was compiled with 4 alternative answers, namely, strongly agree, agree, disagree and disagree as given in Table 1. The systematic preparation of the labwork module is done by compiling the labwork material and the type of visualization (media) used. In presenting this labwork material, there are several components that must be considered, namely the title of the labwork material.

Development

The labwork material development stage is a follow-up to the design that has been carried out. Science labwork material developed at this stage will be evaluated/assessed by fellow lecturers/teachers. The structure or framework chosen in developing practical material is short, clear, concise and in accordance with needs.

After everything is finished. To get a valid and good module, the development is to produce a product that has been revised based on input from the assessor. The assessment of this labwork material is intended to be able to see the feasibility of the material in the developed labwork material. The assessment covers aspects of the feasibility of the material and the feasibility of the media carried out by two chemists with energy research fields. The results of the assessment of labwork teaching materials get criteria Very feasible (95%) so that labwork materials can be used in the learning process.

Figure 1. The situation of evaluation and implementation activities

Implementation

The assessment of student questionnaire responses aims to assess student interest in the topic, determine the quality of labwork teaching materials and test student acceptance of the given topic. Figure 1 shows the atmosphere when the evaluation and implementation was carried out in one of the classrooms in the school. Grade 12 students were selected to provide an assessment by filling out a given questionnaire. Assessment of the material presented can be more objective because these students have studied science material extensively. Table 2 shows the results of the assessment by students of the practical teaching materials through the questionnaire given.

Table 2. The results of student questionnaire assessments

Element of assessment	Student respondents										Total
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	
1	4	4	4	3	3	3	4	4	4	4	37
2	4	4	4	4	3	3	4	4	4	3	37
3	3	4	3	3	4	3	4	4	4	4	36
4	4	3	3	4	3	2	4	4	4	3	34
5	4	4	3	3	3	2	4	4	3	3	33
6	3	4	3	4	3	2	4	4	3	4	34
7	4	4	3	3	3	3	4	3	3	4	34
8	4	3	3	3	3	3	4	3	4	3	33
9	4	4	3	3	3	3	3	4	4	3	34
10	4	4	3	3	3	3	3	4	4	4	35

The results of the processing of the anget responses that were distributed to students was an average value of 3.47 with an interest percentage of 86.8% (very interested). It can be said that students are very interested in the teaching material provided. The materials developed are as follows.

Introduction

Energy is available in various forms, including radiation, chemical, mechanical, gravitational potential, electric potential, electricity, high temperature, solar, latent and kinetic heat. There are various methods, plans, technologies and systems for storing various forms of energy. The choice of energy storage technology is usually determined by the application, the economics of integration in the system, and the availability of resources. Energy storage technology involves the process of converting energy from one form that is difficult to store to another that is available for storage (Syarif et al., 2019).

Energy storage is a method or tool for storing several forms of energy that can be taken at a certain time for various purposes. All forms of energy that are included in potential energy (eg chemical energy, electrical energy, etc.) or thermal energy can be stored. Current commercial energy storage systems can be categorized into mechanical, electrical, chemical, thermal, and nuclear energy. Unlike organic energy storage media such as wood or coal, electricity is used as soon as it is first generated.

In today's modern life, electrical energy is an unavoidable main requirement. Electrical energy is a major need for humans. Electrical energy is used in people's lives with only low capacity to the industrial world in very large quantities. Various technologies that exist today, most of them require electrical energy storage devices. For example, cellular phones and laptops require batteries as energy storage devices. So far there has been great interest among researchers to develop and perfect more efficient energy storage devices.

Solving problems in storing energy for electrical purposes began with the invention of the battery for the first time. This electrochemical energy storage device has limited use due to its small capacity and high cost of manufacture compared to the electrical energy produced by an electric generator at the same amount of energy. Another solution to the same problem is the invention of supercapacitors.

Energy storage devices have levels based on power density and energy density, for energy density sequentially from small to large are conventional capacitors, supercapacitors, batteries, fuel cells, while based on power density from the smallest sequentially are fuel cells (fuel cells) batteries, supercapacitors and last is conventional capacitors. The supercapacitor occupies the area between a conventional capacitor and a battery. Despite having a higher capacitance value than conventional capacitors, supercapacitors have not yet reached the energy density of batteries and fuel cells.

Supercapacitor with Carbon Electrodes

Supercapacitors have two sides of electrodes and a separator that can form two electrical layers or is called an electric double layer when electrified. The electric double layer occurs not only on the physical surface of the electrode but also on the bulk of the electrode, so that the electric double layer of the electrode formed is much larger than its physical size. However, the process is held at a low electric potential because the bulk phase at the electrode does not have the ability to conduct electrons well. Therefore, in practice to produce a higher potential some electrochemical capacitors must be connected in series, like the series circuit in a battery. The electrical storage density of electrochemical capacitors can be increased by using a porous material as the electrode base material. A commonly known porous material is activated carbon. Activated carbon is made into very small powder particles which in the bulk form a low density mass with holes, resembling a sponge. The overall surface area of even a thin layer of material is much greater than the metal plates used in conventional capacitors allowing for the formation of more charge carriers, namely electrons. Since the amount of electric charge is directly proportional to the energy stored in the electrochemical capacitor, energy is stored in the capacitor. The arrangement of the components in the capacitor consists of two pieces of monolithic carbon as electrodes; current-collecting plates which can be made of titanium or aluminium, plate graphite, stainless and alloys; separator material made of PTFE cloth - glass or PTFE sheet of minimum thickness possible, applicator made of stainless steel rod and capacitor housing frame made of PTFE cylinder, polyethylene, or acrylic resin. The construction is made by sandwiching the separating material with carbon electrodes on both sides. The electrodes and separator are then flanked by a current-collecting plate. The filling of the electrolyte solution is carried out through the side of the cylinder using a syringe after the construction is tightly closed in the housing.

Supercapacitor Manufacturing

An explanation of the definition of a supercapacitor and its relation to labwork in schools and the use of related instruments, namely a multimeter (Figure 2(b)). Multimeters are now easily available and purchased at very affordable prices. Materials and the manufacture of supercapacitors is done using materials (Figure 2(a)) that can be found easily around.

The electrode material is charcoal and must be conductive. Most of the charcoal produced traditionally in one cycle is not conductive. At this stage, the selection step for charcoal is treated. Charcoal is checked one by one with a multimeter to get a conductive charcoal. Conductive charcoal is formed using abrasive paper to obtain a square-shaped charcoal with a size of 2 cm x 3 cm. Two pieces of charcoal that have been shaped are then used as electrodes. To form the electrolyte used PVA and an electrolyte compound attached to the two electrodes. The supercapacitor is formed after the two electrodes already contain electrolyte.

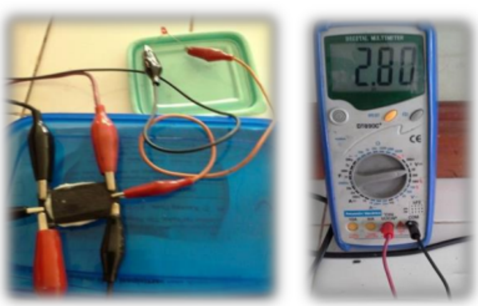

Figure 2. (a) Supercapacitor that has been made and installed with LED lights (b) Measurement tool for a circuit using a supercapacitor.

Evaluation

The last stage in ADDIE is the evaluation stage. The evaluation stage is a stage to measure the achievement of labwork module development. The researcher assessed the feasibility of the labwork module developed based on the results of the validation of the labwork module and the results of student responses after using the proposed labwork teaching materials. The overall results of the feasibility assessment show that the average is in the very suitable category for use. The feasibility of the labwork material is then measured by the response of student participants to show student interest, namely very interested.

Several questions regarding the meaning of supercapacitors and batteries and their relation to labwork in schools and the use of related instruments were presented to evaluate student responses. Explanation of the definition of supercapacitor and its relation to labwork at school and the use of existing instruments to provide understanding and attract enthusiasm from students. The activity of providing material and evaluation lasted for approximately 2 hours and at the end of the session the presenters provided an opportunity for students to ask questions related to the material that had been delivered. Several questions were received from the counseling participants regarding the content of the material. Evaluation related to the provision of material that has been delivered by asking questions and providing opportunities for participants to answer these questions. Evaluation is delivered after answering questions from students. The evaluation activities were carried out well, even the students looked enthusiastic and hoped that the extension activities could continue with the provision of other materials. The activities carried out included counseling on supercapacitors, batteries and potentiostat measuring devices accompanied by manufacturing demonstrations and their relationship with labwork at school.

4. CONCLUSION

The development of practical teaching materials for senior high schools is suitable for use by educators in science learning based on the assessment of the lecturers / teachers resulting in an assessment with a 95% feasibility percentage (very feasible). Student responses indicate that an average of 86.8% are included in the very interested category. It can be said that students are very interested in learning to use the material presented. The evaluation and implementation activities went smoothly, interspersed with questions and answers, which were previously filled with the manufacture of a supercapacitor, containing an explanation of the materials used to make a supercapacitor.

In connection with the development of the labwork module, it is necessary to follow up to obtain better and quality science labwork material. The data above provides several recommendations for the development of labwork materials that support renewable energy programs that need to be more and more diverse so that students in secondary schools can understand this government program that is being launched, research in schools conducted by teachers and students so that schools can produce students who are perform better in larger events.

Acknowledgement: DIPA Badan Layanan Umum Universitas Sriwijaya 2020 funded the writing of this article with SP DIPA-023.17.2.677515 / 2020, revision 01, date March 16 2020. In accordance with the Rector's Decree No: 0685 / UN9 / SK. BUK.KP/2020/ on date July 15 2020.

Conflicts of Interest: The authors declare no conflict of interest.

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