Student’s perspective about electrical voltage of fruit cells through STEM

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Abstract. The use of batteries in electronic tools can cause environmental pollution. This problem can be solved by using natural ingredients that can replace conventional batteries as a source of electrical voltage. This topic is suitable for students to learn in class by reviewing aspects in the fields of Science, Technology, Engineering, and Mathematics (STEM). For STEM’s activities, we used Yuenyong’s Science-Technology-Society (STS) approach, and for data analysis, we used mixed methods, where quantitative methods to classify the data and qualitative methods to analyze student perspective. In this study, students are given lemons, limes, potatoes, apples, tomatoes, and cucumbers as fruit cells. Then all fruits are connected by coins, nails, cables, multimeters, and LED lamps. The results obtained by students is conventional batteries cells can be replaced by fruit cells. All fruit cells that we used like cucumber, apples, tomatoes, limes, lemons, and potatoes are capable of producing electrical voltage. Cucumbers and tomatoes produce the higher electrical voltage (5.0 volts & 3.0 volts) but have a dim LED’s light, while potatoes, lemons, limes, and apples produce the lower electrical voltage (1.35 volts, 2.0 volts, 2.2 volts, and 3.4 volts) but have bright LED lights.

1. Introduction
The use of electronic goods in human life such as cellphones, laptops, tablets, remote controls, etc. leaves waste that pollutes the environment. In Indonesia, an increase in environmental pollution over the past 9 years has occurred in the cities of East Jakarta, Depok, Serang, Yogyakarta and Manado [1-5]. The increase in the amount of electronic waste in Indonesia is predicted to reach more than 600,000 tons in 2025 [5].

One of the components highlighted from electronic waste is the battery. Not only in Indonesia, but also nearly 50% of the population in several countries in the world such as Thailand, China, Japan, Portugal, Saudi Arabia, and Italy also prefer to dispose of their battery waste in public bins and into the environment around where they live [1, 6-12]. Battery constituents such as zinc (Zn), carbon (C), lead (Pb), cadmium (Cd), etc. can pollute soil, water, and air. Examples of soil contamination include changes in the level of alkali and acidity of the soil, inhibition of growth and development of plants; pollution of water that is poisoning and reducing the existence of aquatic organisms; and air pollution which is the result of evaporation of the substance will poison the respiratory tract of humans and animals [13].

One solution to overcome environmental pollution due to battery waste is to make environmentally-friendly batteries or later known as bio-batteries. The results of previous studies provide information that batteries cells as a source of electrical voltage can be replaced by fruit cells. These cells can be made...
from fruit’s peels, fruit’s pasta, and fruit’s flesh. Khairiah, Fadilah, and Suciati found that durian peels, orange peels, and banana peels can be used as fruit cells to produce electrical voltage [14-16]. Then another research comes from Togibasa, he found that tropical almond fruit’s pasta can be used as fruit cells to produce electrical voltage too [17]. For fruit flesh, Fadli, Kholida, and Wibig found that pineapple, oranges, mangoes and cucumbers can be used as fruit cells and produce electrical voltage [18-20].

The purpose of our study was to identify the student's perspective on the electrical voltage of fruit cells through Science, Technology, Engineering, and Mathematics (STEM) education. We use this social issue in STEM education because STEM has several advantages. Some of the advantages of STEM education are that it can improve student's scientific literacy, increase student activity in the classroom, train and develop student skills [21, 22]. Another advantage is STEM can help students in higher education to raise their scientific productivity in Germany, France, Belgium, and Luxembourg [23]. Also, it was found that research on STEM education was successfully carried out and published massively in other countries such as the United States (US), Canada, and Australia for more than a decade [24].

The novelty of this research is how to teach students that conventional battery cells can be replaced by fruit cells as a source of electrical voltage. Because the previous research on fruit cells was carried out by some researchers just as their scientific activities to solve environmental pollution problems in the field of research, not as learning activities in the field of education. Therefore we are interested in bringing this topic to the field of education through STEM activities in the classroom by comparing the ability of the electrical voltage produced by various kinds of fruit.

2. Research Methods

We chose STEM education’s plan to make fruit cells through Yuenyong’s Science-Technology-Society (STS) approach which the activity consisted of 6 steps (shown in Figure 1), like 1) Identification of social issues, 2) Identification of solution, 3) Need for knowledge, 4) Decision-making, 5) Development of product, 6) Test and evaluation, and 7) Socialization product [25]. In the first step, students are given problems with environmental pollution due to the high use of batteries in electronic devices. Therefore, they need an environmentally friendly battery that comes from natural ingredients. In the second step, students are directed to identify battery cell manufacturing solutions from these natural ingredients in the aspects of Science, Technology, Engineering, and Mathematics (STEM). In the third step, students conduct experiments to make battery cells from natural ingredients so as to obtain any variables that affect it. In step four, students create the most attractive and efficient design drawings with produce the brightest light on LED lamps. In the fifth step, students make a battery cell product from natural ingredients based on a previously made design. In the sixth step, students conduct testing and evaluation of their products. While in step seven, students make presentations of their final product.

**Figure 1.** Six steps of Yuenyong’s Science-Technology-Society (STS) activities.

In this study, the ingredients were apples, tomatoes, cucumbers, potatoes, lime, and lemons. While the tools were multimeters, cables, LED lights, coins, and nails. For the assessment instruments, we used STEM identification worksheets and Product Evaluation worksheets. The results data were the student's perspective of STEM identifications of fruit cells, Fruits cells design, Light of LED lamp, and Fruits cells voltage. The methods used in this study was mixed methods, where the quantitative method to classify the data and the qualitative method to analyze student perspective [26]. Total participants in this study were 65 students who divided into 6 groups for each class A and B of the science education study program, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang.
3. Result and Discussion

The results of student identification data on aspects of STEM in the fruit’s cell are shown in table 1. From table 1, it appears that the results of student identification of STEM are true with a percentage 83% and false with a percentage 16%. The cause of student error is the answer 'make battery cells based on fruits' in the Engineering aspect is not appropriate, because the answer is included in the Science aspect especially Biology. While the answer "the use of ohm's law" is incorrect because the answer is included in the Science aspect, especially Physics.

| Aspect             | Answer                                                                 | Groups | True/False |
|--------------------|----------------------------------------------------------------------|--------|------------|
| Science            | The electrical circuits, Potential difference, and its currents       | 10     | True       |
|                    | Source of electrical voltage from electrolyte material                | 6      | True       |
|                    | The quality of LED lights                                            | 4      | True       |
|                    | Electrolyte properties of the solution                               | 10     | True       |
|                    | Utilization of fruits as a natural materials                          | 12     | True       |
| Technology         | Alternative batteries cells                                          | 12     | True       |
|                    | Reduction of environmental pollution due battery waste               | 4      | True       |
| Engineering        | Make an electrical circuit                                           | 12     | True       |
|                    | Make battery cells based on fruits                                  | 2      | False      |
| Mathematics        | Calculation on a multimeter                                         | 4      | True       |
|                    | Calculate the electric power                                         | 8      | True       |
|                    | The use of ohm’s law                                                 | 6      | False      |

3.1. Student’s Perspective of Product’s Design of The Fruit’s Cells

The results of the fruit cell product design data that were successfully made by students during the learning activities are shown in Figure 2. In Figure 2, the product’s design value of potatoes, lemon, apples, and cucumber is 50, with quite good criteria. While the product’s design value of limes is 75, with good criteria. Finally the product’s design value of tomatoes is 92, with very good criteria. This criterion is based on whether or not the shape, size, and art of the product design made by students.

3.2. Student’s Perspective of LED Lights and Voltage to Fruit Cells

The results of students’ viewpoint data on the LED lights produced from fruit cells, namely potatoes, lemons, lime, and apples produce bright LED lights, while tomatoes and cucumbers produce dim lights. This is supported by the value of the voltage generated by each fruit as in Figure 3(a). The electrical voltage from potatoes are 1.35 volts, lemons are 2 volts, lime are 2.2 volts, tomatoes are 3 volts, apples are 3.4 volts, and cucumbers are 5 volts.

These results provide two interesting information for students. The first one is cucumbers turn out to produce the highest electrical voltage of all fruits such as apples, tomatoes, limes, lemons, and potatoes. In this research, students found that the electrical voltage produced by six cucumbers is 5 volts. This result is similar and compatible with previous research conducted by Wibig. He found that one cucumber can produce an electrical voltage of 0.8 volts [20]. So if we have six cucumbers, the electrical voltage will be around 4.8 volts.

The second one, although cucumbers have the highest electrical voltage, it produces a dim LED lights, while potatoes, lemons, lime, and apples produce bright LED lights. Student try to identify this information from similar previous studies, but there is no result. Students then think to identifying this information by linking it to the fruit's acidity or pH. The pH results of each fruit obtained by students are shown in Figure 3(b). The details of the pH value of each fruit are pH 5 for potatoes; pH 3.2 for lemons; pH 3 for limes; pH 3.5 for Tomatoes; pH 3.7 for Apples; and pH 5.5 for cucumbers.
Based on the results of previous studies from Kholida, there is a relationship between acidity (pH) with an electrical current. She found that the lower acidity fruits, the stronger the electrical current. While the higher acidity fruits, the weaker the electrical current strength [19]. Cucumbers have the highest acidity and weaker electrical current, but the electrical voltage is high. That's why the LED light of cucumbers could be dim because the electrical power is low. This properties also applies to other fruits. Please note that bright lights or dim lights are determined based on electrical power. Because electrical power value is the product of the electrical current and its current.

4. Conclusion
The student’s perspective about the electrical voltage of fruit cells gives some conclusion. Conventional batteries cells as a source of electrical voltage can be replaced by fruit cells. We apply this topic to learning activities in the classroom through STEM education. All fruit cells that we used like cucumber, apples, tomatoes, limes, lemons, and potatoes are capable of producing electrical voltage. Cucumbers
and tomatoes produce the higher electrical voltage but have a dim LED’s light, while potatoes, lemons, limes, and apples produce the lower electrical voltage but have bright LED lights.

Things that have not been completed in this study are to measure how long it takes the fruit in order to continue to produce electricity. In addition, fresh or not the condition

Recommendations for further researchers so that students get a more complete understanding of fruit cells is they need to identify the content of free ions and constituent substances in the fruit. The price of the fruit must also be considered by students given that one fruit can have a higher price than a small battery.

References
[1] Ardi R and Handafiah F 2019 Mapping electronic waste flows in depok, west java IOP Conf. Ser.: Earth Environ. Sci. 401 012005
[2] Safrudin A and Sitorus A 2010 In the red zone survival, lead exosure, and its impact of ulab recycling in jakarta (Jakarta: Tempo)
[3] Fauzia F R, Weslyme S A, and Wiharjo M G M 2017 E-waste, money and power: mapping electronic waste flows in yogyakarta, indonesia J. Environ. Dev. 24 1
[4] Andarani P and Goto N 2012 Preliminary assessment of economic feasibility for establishing a households’ e-waste treating facility in Serang, Indonesia Int. J. Environ. Sci. Dev. 3 562
[5] Hanafi J, Kristina H J, Jobilione G, Christiana A, Halim V, Sastoso D, and Melini E 2011 The prospects of managing WEEE in Indonesia (Braunschweig: Springer) pp 492-496
[6] Hongting L, Jingui D, Aimin W, Songlin Z, Huiru Y, and Zhang J 2019 Recycling and treatment of waste batteries IOP Conf. Ser.: Mater. Sci. Eng. 612 052020
[7] Hu S W 2015 The status survey on waste battery recycling and reuse in wuhan city The Guide of Sci. & Edu. 6 190
[8] Guo T J 2001 Recycling of waste batteries in japan China Res. Comp. Uti. 11 36
[9] Mylarappa M, Venkata Lakshmi V, Vishnu Mahehs K R, Nagaswarupa H P and Raghavendra N 2016 A facile hydrothermal recovery of nano sealed MnO2 particle from waste batteries: An advanced material for electrochemical and environmental applications IOP Conf. Ser.: Mater. Sci. Eng. 149 012178
[10] Karnchanawong S and Limpiteeprakan P 2009 Evaluation of heavy metal leaching from spent household batteries disposed in municipal solid waste Waste Manag. 29 550
[11] Xara S M, Delgado J N, Almeida M F, and Costa C A 2009 A facile hydrothermal recovery of nano sealed MnO2 particle from waste batteries: An advanced material for electrochemical and environmental applications Waste Manag. 29 2121
[12] Belardi G, Ballirano P, Ferrini M, Lavecchia R, Medici F, Piga L, and Scoppettuolo A 2011 Characterization of spent zinc-carbon and alkaline batteries by SEM-EDS, TGA/DTA and XRPD analysis Thermochim. Acta. 526 169
[13] Li Q R, Su B, and Li S C 2008 Trace Element Cobalt, Nickel and Human Health, Guangdong Trace Elem. Sci. 1 66
[14] Khairiah, Siregar S M, Siregar J, Nasution L A, and Daulay A H 2018 The Electrical properties of nanomaterials derived from durian skin waste by using a various types of electrodes for bio-battery application J. Phys.: Conf. Ser. 1120 012085
[15] Fadillah S, Risa R, and Kim M P 2015 Making biomaterials from banana skin waste (musa paradisiaca) Pros. Simp. Nas. Ino. and Pemb. Sains
[16] Suciati, Sri W, Asmarani S, and Supriayanto A 2019 Analysis of orange flesh and orange peel as an electrolyte solution for electric voltaic cells J. Teori dan Apl. Fis. 7 1
[17] Togibasa O, Haryati E, Dahlan K, Ansany A, Siregar T, and Liling M N 2019 Characterization of bio-battery from tropical almond paste J. Phys.: Conf. Ser. 1204 012036
[18] Fadli U M, Legowo B, and Purnama B 2012 Demonstration of pineapple voltaic cells (ananas comosus l. Merr) Ind. J. App. Phy. 2 1
[19] Kholida H, and Pujayanto P 2015 Relationship of electric current with acidity of oranges and
mangoes Pros. Sem. Nas. Fis. dan Pend. Fis. 6 1
[20] Wibig 2010 Cucumber power Phys. Educ. 45 331
[21] Ismail, Permanasari A, and Setiawan W 2016 STEM virtual lab : an alternative practical media to enhance student’s scientific literacy JPII 5 239
[22] Thai Q B, Cao T K, Ngo T N, Nguyen T T H, Hoan V Q, Quang P H and Chu V H 2019 Teaching and learning about magnetic field and electromagnetic induction phenomena integrated science, technology, engineering and mathematics (stem) education in vietnamese high schools J. Phys.: Conf. Ser. 1340 012031
[23] Powell J J W, and Dusdal J 2017 Science production in germany, france, belgium, and luxembourg: comparing the contributions of research universities and institutes to science, technology, engineering, mathematics, and health Minerva 55 413
[24] Chomphuphra P, Chaipidech P, and Yuenyong C 2019 Trends and Research Issues of STEM Education: A Review of Academic Publications from 2007 to 2017 J. Phys.: Conf. Ser. 1340 012069
[25] Seattha P, Tupsai J, Sranamkham T and Yuenyong C 2016 Students’ view on STEM in learning about circular motion through STS approach AIP Conf. Proc. 1775 1–9
[26] Creswell J W 2014 Research design: qualitative, quantitative, and mixed methods approaches (United States of America: SAGE) p 375