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Development of Universal Indicator from Organic Waste Material

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Abstract: This research aims the development of universal indicators from organic waste materials. This is a research and development (R&D) with a modified ADDIE model. The universal indicator developed was implemented for students of class XI MIPA at Senior High School in Bantul, Yogyakarta. The data collection methods used are interviews, product validation sheets, observations, tests, and questionnaires. The results showed that the universal indicator can determine a pH value of 0-14 and can be stored for 11 days. The product developed has met valid criteria with an average percentage obtained of 94.20% based on validators evaluation. The product developed has met effective criteria with an average percentage obtained of 95.00% based on students' science skills and 75.00% based on student learning outcomes and practical criteria with an average percentage obtained of 87.40%.

Keywords: Development; Organic Waste Material; Universal Indicator

Introduction

The acid-base is one of the oldest and fundamental topics in chemistry subject (de Vos & Pilot, 2001; Drechsler & Van Driel, 2008). According to Lumolos et al. (2019) and (Wusqo 2015), learning activities regarding the topic of the acid-base must integrate practical activities so the students get direct experience in constructing the concept. Duda (2010) added that practicum-based learning can be used as an alternative to chemistry learning. Based on the curriculum standards, one of the practical activities carried out on the acid-base topic is that students are able to design and conduct an experiment related to testing the level of acidity or alkalinity of a substance (Lumolos et al., 2019; Rahmawati et al., 2020). Testing the level of acidity or alkalinity of a substance can use an acid-base indicator or a pH meter. Plants that can be used as acid-base indicators are colored, but not all colored plants can give color changes under acidic or alkaline conditions (Listyarini et al., 2019). In general, the making of natural indicators carried out in schools is still conventional.

Based on the results of interviews with chemistry teachers in class XI senior high school in Bantul, Yogyakarta, natural indicators made by students are still in solution form. The indicator solution cannot be stored because it can cause an unpleasant odor and produce less accurate data if used for retesting. This finding is in line with Wasito et al. (2017) that explain that natural indicators made in the form of a single solution have several limitations, namely they are not durable, less stable, less practical to use, and the measurement of the pH trajectory is still narrow.

Based on this problem, it is proposed the development of natural indicators in the form of universal indicators. The indicator is capable of measuring pH 0 – 14, can be stored and is practical to use. The material for making this universal indicator comes from organic material waste. Organic waste in Indonesia is increasing dominating 60% of other types of waste in 2019 (Permana, 2019). Some natural wastes such as purple cabbage, purple sweet potato skin, onion skin, and red apple skin contain anthocyanin compounds (Castañeda-Ovando et al., 2009; Mattioli et al., 2020).

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Anthocyanins have been most frequently used to discuss acid-base chemistry (Garber et al., 2013). The stability and color of anthocyanins are influenced by pH (Hambali et al., 2014; Liu et al., 2018) These findings support the fact that anthocyanins are used as natural indicators of acid-base because of their ability to interact in both acidic and alkaline conditions (Sampaio et al., 2020).

Based on this, natural material waste has the potential as a basic material for making acid-base indicators. The development of universal indicator of waste materials will be equipped with instructions for use and color indicator range so it can be used for practical activities and can identify students' science process skills.

Method

This is a research and development (R&D) with ADDIE model. The ADDIE stage consists of 5 stages, namely Analysis, Design, Development, Implementation, and Evaluation. The product was used by eight students of class XI MIPA at Senior High School in Bantul, Yogyakarta. The instruments used in this study were interview sheets, product validation sheets, observation sheet validation sheets, practicum worksheet validation sheets, questionnaire response sheet validation sheets, observation sheets, and student response questionnaire sheets.

Product validation results are obtained in the form of qualitative data derived from the validator's suggestions and quantitative data. The percentage of product validation results is calculated using the following Equation 1. The percentage results obtained are compared with the product validity criteria presented in Table 1.

$$V - ah = \frac{TSe}{Tsh}\ x\ 100\% \tag{1}$$

Note:
V – ah = Percentage of validation results
TSe = The total score of the validator of each aspect
TSh = the maximum score for each aspect

Table 1. Product Validity Criteria

Percentage (%)	Validity
85.01 - 100	Very valid
70.01 – 85.00	Valid
50.01 – 70.00	Less Valid
01.00 – 50.00	Not Valid

(Akbar, 2015)

The results of the observation of students' science process skills were analyzed using the following Equation 2. The calculation of the percentage obtained compared to the skill category scale is presented in Table 2.

$$P = \frac{f}{N}\ x\ 100\% \tag{2}$$

Note:
P = Percentage
f = Total scores from observers for each indicator of science process skills
N = The maximum score for each science process skill indicator

Table 2. Skill Category Scale

Score	Skill Category
80.00 – 100.00	Very good
60.00 – 79.99	Good
40.00 – 59.99	Satisfactory
20.00 – 39.99	Poor
0.00 – 19.99	Bad

(Arikunto, 2010)

The results of students' answers to the questions are calculated using the following Equation 3. The percentage obtained is compared with the criteria for student learning outcomes presented in Table 3.

$$\text{Final score } = \frac{total\ score\ obtained}{maximal\ score}\ x\ 100\% \tag{3}$$

Table 3. Criteria for Student Learning Outcomes

Score	Criteria
81 – 100	Very good
61 – 80	Good
41 – 60	Satisfactory
21 – 40	Poor
0 – 20	Bad

(Arikunto, 2010)

To assess the effectiveness of the product from student learning outcomes using the following Equation 4. The percentage obtained is compared to the product effectiveness criteria presented in Table 4.

$$\text{Percentage } = \frac{P}{n}\ x\ 100\% \tag{4}$$

Note:
P = Number of students who scored > Minimum Mastery Criterion
n = Number of students

Table 4. Product Effectiveness Criteria

Criteria	Percentage (%)	Criteria
1.	81.00 - 100	Very effective
2	61.00 - 80.00	Effective
3	41.00 - 60.00	Fair
4	21.00 - 40.00	Less effective
5	1.00 - 20.00	Not effective

(Riduwan, 2011)

The results of the student response questionnaire were analyzed using the following Equation 5. The percentage obtained is compared with the product practicality criteria presented in Table 5.

$$P = \frac{\sum Se}{\sum Sh} x \ 100\% \quad (5)$$

Note:
P = Percentage
$\sum Se$ = The number of students' answer scores for each aspect
$\sum Sh$ = The maximum score for each aspect

Table 5. Product Practicality Criteria

Percentage (%)	Practicality
81 < P ≤ 100	Very practical
61 < P ≤ 80	Practical
41 < P ≤ 60	Quite practical
21 < P ≤ 40	Less practical
0 < V ≤ 20	Not practical

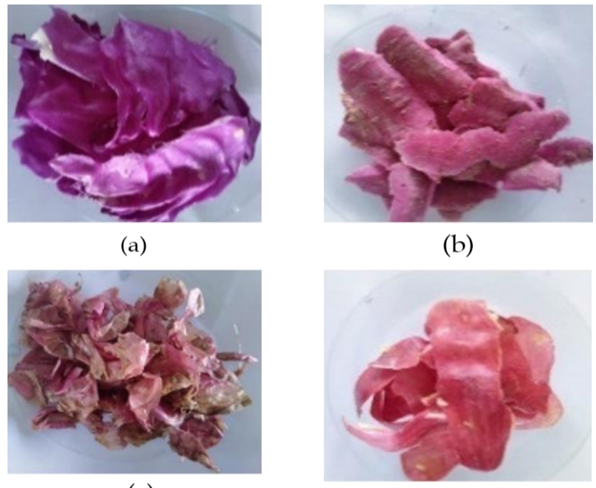
(Akbar, 2015)

Result and Discussion

The product development refers to the ADDIE model which is modified from the Branch (2009) model. The analysis phase involved interviewing the chemistry teachers at the senior high school in Bantul, Yogyakarta. Based on the results of interviews with teachers, acid-base practicum has been carried out using natural indicators but in the solution form, which cannot be stored. In addition, the indicator solution cannot be used to determine the investigated solution's pH. Based on these problems, developing a product that is a universal indicator of natural material waste is necessary to improve the quality of learning in acid-base practicum activities.

The next phase is to carry out a design for the product being developed. In this study, the natural waste materials used were purple cabbage, purple sweet potato skin, onion skin, and apple skin. The materials used are shown in Figure 1 (a –d).

The four ingredients contain anthocyanin compounds that can change color in acidic and alkaline conditions. Anthocyanins are organic compounds that can change color with changes in pH values so that these compounds can be used as acid-base indicators (Deman, 1997). The natural material waste is extracted using methanol as a solvent. Methanol was chosen because it has the same polarity as anthocyanins. In the study of Romandanu. et al. (2014) methanol solvent was able to extract flavonoids from lotus flowers with the resulting yield of 0.708%.



(a) (b) (c) (d)

Figure 1. (a) Cabbage (b) Sweet potato skin (c) Shallot skin (d) Red apple skin

The extraction method used for the extraction of the four natural waste materials is maceration. This is because the maceration method is easy and does not require a heating process to minimize the possibility of damage to the active substance to be extracted (Susanty & Bachmid, 2016). The maceration method was carried out by soaking the four natural material wastes with methanol in a ratio of 1:4. The use of this ratio is because according to Jayanudin et al. (2014) the greater the ratio of the material to the solvent used, the wider the contact between the solvent and the solid so that the distribution of the solvent to the solid is evenly distributed. The maceration time is 24 hours, and Amelinda et al. (2018) stated that the longer the maceration time used, the greater the extract yield. The results of the extraction of purple cabbage are purplish pink, purple sweet potato peel extract is faded brown, onion skin extract is yellowish red, and red apple skin extract is red.

The manufacture of universal indicators requires several papers containing active compounds that can change color in acidic and alkaline conditions. Therefore, the extract obtained was made in paper form to form indicator paper. The indicator paper was made by soaking Whatman paper with the extracts for 24 hours at room temperature. The immersion process will make the dye absorbed strongly by the paper because the paper has a polar nature (Sastrohamidjojo, 1985). The dye with the same polarity as the paper will be retained longer. The indicator papers then were dried at room temperature and stored. This treatment was carried out because anthocyanins were easily decomposed at high temperatures and changed in structure, resulting in changes in color pigments (Sutrisno, 1978). The indicator paper resulting from purple cabbage extract was purple whereas the indicator paper from purple sweet potato peel extract was pale pink. In addition, the indicator paper from red onion peel extract was light pink, and the indicator paper from red apple peel extract faded purple. Each of the indicator paper color from natural materials was quite different even though the four wastes of natural materials contain the same anthocyanin. This is because each of the four natural waste materials has a different type of anthocyanin.

The universal indicator was made by adapting the shape of commercial universal indicators. For each universal indicator, there are four color variations derived from four extracts of natural waste materials. The universal indicator was made by cutting four indicator papers containing extracts of different natural waste materials and cutting them to a size of 0.5 x 0.5 cm. Each indicator paper is glued to the supporting paper using an adhesive. The order of indicator paper from bottom to top is red apple skin, onion skin, purple sweet potato skin, and purple cabbage. The universal indicator size obtained is 7.0 x 0.5 cm which is shown in Figure 2. The universal indicator box was made to store the product. The box was equipped with instructions for use and pH color range. The front side and backside of the universal indicator box are shown in Figure 3 and Figure 4 respectively.

Figure 2. Universal Indicator from Organic Waste Material

Figure 3. Universal Indicator Box Appearance (front side)

Figure 4. Universal Indicator Box Appearance (backside)

The pH color range of the universal indicator was determined by testing universal indicators using a buffer solution with a pH of 0-14. The pH color range of the universal indicators is shown in Figure 5 and Figure 6.

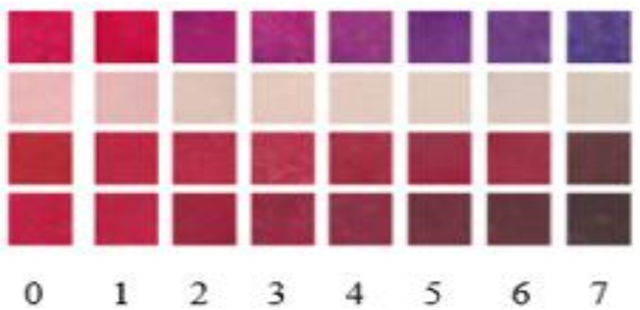


Figure 5. pH Color Range (pH 1-7)

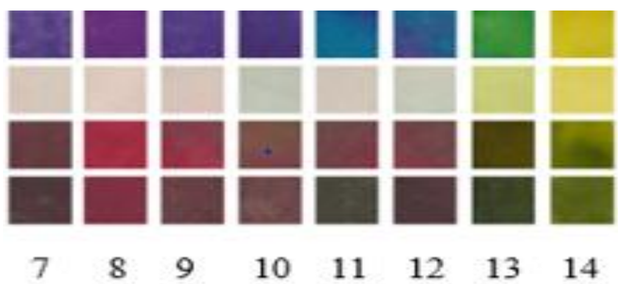


Figure 6 pH Color Range (pH 7-14)

It is shown that several pH colors ranges have almost the same color e.g. pH 0 with pH 1, pH 2 with pH 3, pH 3 with pH 4, pH 5 with pH 6, and pH 9 with pH 10. The similarity of the color range is due to the limitations of natural material waste whose color changes at each pH are similar. The durability test was performed for 20 days. This test was carried out by storing the product in a closed container and observing the change in color appearance for 20 days. The color appearance of the product does not differ for 20 days. This showed that the anthocyanins contained in the universal indicator did not decompose. The comparison of the universal indicator with the research of Wasito et al. (2017) shows that the universal indicator has sufficient stability.

In order to determine the performance of the universal indicator, the response tests were carried out for several days. The response tests were carried out by testing the product using a buffer solution of 0-14. It was found that the universal indicator can be used until the 11th day. The color of the universal indicator started to change on the 12th day because the color changes deviated from the pH color range in Figure 5 and 6.

The universal indicator was then validated by validators before being used by students. Product validation was done by assessing several aspects. The results of product validation are shown in Table 6.

Table 6. Product Validation Results

Aspects	Average Percentage (%)	Criteria
Esthetics	93.13	Very valid
Completeness	100.00	Very valid
Efficiency	96.25	Very valid
Accuracy	90.00	Very valid
Durability	85.00	Very valid
Innovation	100.00	Very valid
Educational value	95.00	Very valid
Average percentage (%)		94.20
Criteria		Very valid

Based on Table 6, the innovation aspect gets the highest score because the product utilizes natural waste as the main ingredient. In terms of completeness, it shows the highest score because the product is stored in a closed box and is equipped with instructions for use and pH color range. In general, every aspect has very valid criteria based on Table 5 (Akbar, 2015). Thus, the product developed has met the valid criteria then it is feasible to be implemented for students.

The implementation of the product to students was carried out to determine the practicality and effectiveness of the universal indicator. The universal indicator was used for an acid-base practicum activity. This practicum activity is closely related to the students' science process skills. According to Munandar (2016), the implementation of the practicum prioritizes the science process skills of students during the practicum to achieve good learning outcomes. Astuti et al. (2019) stated that the implementation of the practicum helps students' skills when carrying out practical activities such as observing skills, interpreting data skills, and communicating skills both orally and in writing. Therefore, the results of observing students' science process skills become an assessment to determine the effectiveness of the product. The results of the observation of students' science process skills are shown in Table 7.

Table 7. Results of Observation of Students' Science Process Skills

Science Process Skills Indicator	Average Percentage (%)	Criteria
Using tools and materials	97.00	Very good
Applying the concept	95.00	Very good
Observing	100.00	Very good
Categorizing	90.00	Very good
Interpreting	92.50	Very good
Communication	95.00	Very good

Based on Table 7, the students' skill in using tools and materials is very good. Students' skills in applying the concept got a value of 95.00% with very good criteria. This value was obtained because students were skilled at using the concepts, they received so that practicum activities could be carried out properly. Observation skills of the students got the highest score of 100% with the very good category. This value was obtained because the student could observe the color changes that occurred in universal indicators of natural material waste so they could determine the pH value. The interpreting skills of students are 92.50% which is classified as very good. This interpreting skill was evaluated from the conclusion made by students based on the performed experiment. Communication skills get a score of 95.00% which belongs to the very good category. In general, the average science process skills of students belong to the very good category with a percentage of 95.00%. This shows that the product is an effective criterion because it can determine the science process skills of students. This is in line with Sinambela (2006) that explains that a product can be said to be effective if it achieves the desired goal. In addition, the effectiveness of the product can be determined by student learning outcomes. 75.00% of students pass the minimum mastery criterion. The percentage in the interval of 61.00% - 80.00% was defined as effective criteria (Riduwan, 2011). Therefore, it can be concluded that the product developed has met the criteria for effectiveness.

The practicality of a product was assessed from the students' responses to the questionnaire sheet (Irsalina & Dwiningsih, 2018). The students' responses to the product are presented in Table 8.

Table 8. Students' Responses to the Product

Aspects	Average percentage (%)	Criteria
Product appearance	84.70	Very practical
Product quality	90.00	Very practical
Product function	87.50	Very practical
Average percentage (%)		87.40
Criteria		Very practical

Based on Table 8, the product gets an average 87.40% percentage in very practical criteria (Akbar, 2015), the universal indicator was easy to use, innovative and could determine the pH value.

Conclusion

The product development in the form of a universal indicator of natural material waste has been following the stages of the ADDIE model (Analysis, Define, Development, Implementation, Evaluation). The universal indicator has met the valid criteria based on the validation results from the validators with an average percentage value of 94.20%. The product has met the effective criteria with an average percentage obtained of 95% based on students' science skills and 75.00% based on student learning outcomes. The product has also met the practical criteria from the results of students' responses with an average percentage of 87.40%.

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