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Soap Making Project from Waste Cooking Oil for High School Students' Chemistry Learning: Qualitative Content Analysis

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Abstract: Waste Cooking Oil (WCO) is one of hazardous waste causes serious issues, including environmental and health issues. WCO can be utilized in several bioproducts to reduce the potential of its problems. The purpose of this study is to create teaching-learning sequences from the context of utilization of waste cooking oil into soap. The teaching-learning sequences can be used as a basis to construct lesson design or teaching materials with project-based learning model. This is in line with curriculum in Indonesia known as "Kurikulum Merdeka" for a program called "Projek Penguatan Profil Pelajar Pancasila (P5)". This research used Qualitative Content Analysis as a method with four stages including material collection, descriptive analysis, category selection, and material evaluation. Data were collected through fourteen literatures analysis and expert validation. Validation experts are from an experienced chemistry teacher and two lecturers from chemistry education field. Validation results the teaching-learning sequences' is suitable for use for learning activity in terms of content. The result of this study is a teaching-learning sequences which divided into four sections including: (A) The Phenomenon of Waste Cooking Oil, (B) The Composition of Waste Cooking Oil and The Utilization of Waste Cooking Oil, (C) The Soap Making Process with WCO, and (D) The Benefit of WCO Utilization into Soap.

Keywords: Chemistry Learning; Content Analysis; Kurikulum Merdeka; Teaching-Learning Sequences (TLS); Waste Cooking Oil; Qualitative Content Analysis

Introduction

Project-based learning is one of the student-centered models that provides students to participate in real problem-solving and knowledge construction with real life problems that are relevant to learning topic (Guo et al., 2020). Project-based learning (PjBL) promotes students to work collaboratively in groups to create an innovative product for the solution of the problems, the creation of product distinguishes PjBL from another student-centered model (Guo et al., 2020). The application of project-based learning as learning process in line with curriculum in Indonesia known as "Kurikulum Merdeka". Kurikulum Merdeka hold a program called "Projek Penguatan Profil Pelajar Pancasila (P5)" to increase students's character such as believing and being devoted to God Almighty and having noble morals, global diversity, cooperation, independence, critical thinking, and creativity (Kemendikbudristek, 2021). Those characters can be improved by using PjBL as learning process (Fourniyati et al., 2020; Ijirana et al., 2022; Masbukhin et al., 2023; Situmorang et al., 2022; Sumarni & Kadarwati, 2020). Teaching-learning sequences play a major role in learning outcomes (Guisasola et al., 2017). Andersson and Bach (2005) in Psillos D & Kariotoglou P (2016) define teaching-learning sequences is different from another textbooks that used in worldwide because it

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contains innovative content recontextualization. In Guisasola et al. (2017) Méheut and Psillos (2004) describe teaching-learning sequences is a both research activity and a product.

Waste cooking oil (WCO) is a waste when various edible oils are used to fry food multiple times (Awogbemi et al., 2021). Indonesia has potential to produce waste cooking oil (WCO) around 715 kilotons per year, this data based on the consumption of cooking oil in households and restaurants in urban areas (Kristiana et al., 2022) Inappropriate waste management of WCO can affect environmental problems and human health (Foo et al., 2021). Generally, WCO contains triacylglycerol, glycerol, free fatty acids (FFA), and other polymer compounds that produced by Maillard reaction (Mannu et al., 2019). According to the test, the major chemical compositions in WCO are oleic acid (43.67%), palmitate acid (38.35%), and linoleic acid (11.39%) (Rasman et al., 2018). WCO can be utilized as valuable raw material to produce several products as of waste minimization that contribute to cleaner environments and healthier people (Awogbemi et al., 2021). Soap is one of the examples of utilization product of WCO (Li et al., 2020). Several studies shows that WCO can be utilized to produce soap (Abera et al., 2023; Félix et al., 2017; Maotsela et al., 2019; Mustakim et al., 2020).

Soap is made by saponification process; in aqueous medium, the esters react with strong base such as sodium hydroxide to produce soap (hydrolyzed free fatty acids) and glycerol (Félix et al., 2017).

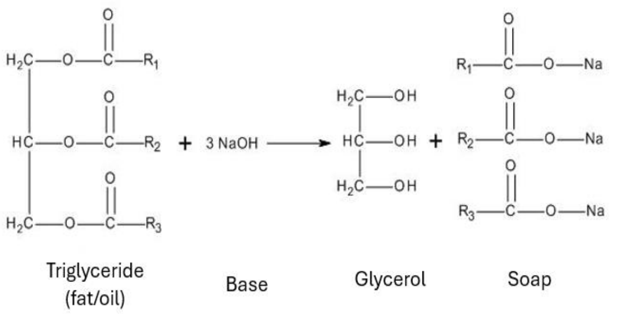

Figure 1. The Saponification Process

Soap that formed by the reaction contains salts of the free fatty acids and glycerol, soap characteristic properties are given by the salts of the free fatty acids (Maotsela et al., 2019). The chemical reaction of soap making can be seen in Figure 1. In this study, the soap making process from WCO was adapted for the learning process in chemistry learning in school. The process is safe for students as there are no hazardous products formed (Maotsela et al., 2019). The learning process expects students to increase their environmental awareness, science literacy and contribute to achieving some of the SDGs (Awogbemi et al., 2021; Félix et al., 2017). Students expected to produce soap as the output of the learning process, this activity can build up their creativity as they can combine other materials to enhance the quality of the soap (Félix et al., 2017). Mustakim et al. (2020) study shows the production of soap cost only Rp578.00. per soap which inexpensive. The required cost to form a soap is cheap, soap that produced by WCO is valuable and will increase students's entrepreneurial skills.

According to statements above, the aim of this study is to design teaching-learning sequences. This research is important because there are no teaching-learning sequences that contain the utilization of waste cooking oil into soap as a learning process. This learning process gives opportunities to students to increase their soft skills such as cooperative, critical thinking, creativity. Additionally, environmental awareness, achieving some of SDGs, and entrepreneurial skills in students arise with the learning process.

Method

In this study, the method used is Qualitative Content Analysis based on Mayring (2000). Qualitative content analysis is an approach of empirical, methodological controlled analysis of texts within their context of communication, following content analytical rules and step by step models, without rash quantification (Mayring, 2000).

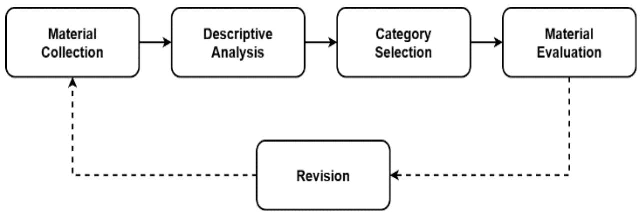

Figure 2. Stages of Qualitative Content Analysis

Figure 2 shows the analysis stages of qualitative content analysis. The analysis stages were carried out in four ways: (1) material collection, (2) descriptive analysis, (3) category selection, (4) material evaluation. The first stage is material collection, materials were collected from various credible sources such as journal articles, conferences, and review articles. The materials collected in table 1 display author, title, year, and code. The second stage is descriptive analysis, all the materials that have been collected are analyzed. Table 2 shows the analysis result and content of the materials. The third stage is category selection, the content that has been analyzed is categorized by pedagogical and didactical aspects. The fourth stage is material evaluation, the result of concepts that are classified evaluated by categories and correlations between concepts. A review of these research activities is required from start to finish to construct a systematic teaching-learning sequences (TLS).

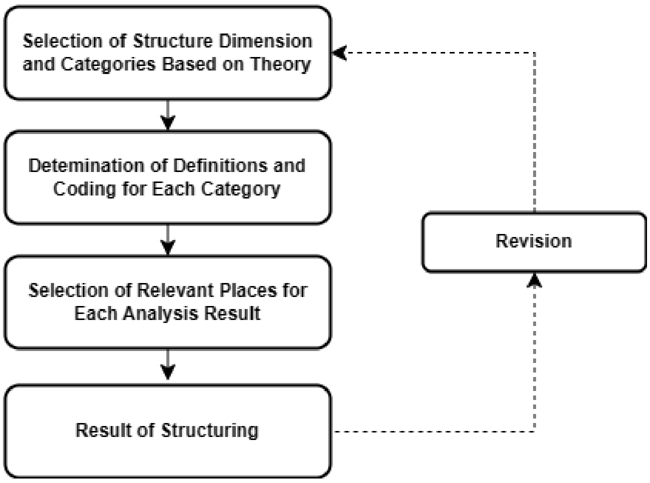

Figure 3. Structuring Process of Qualitative Content Analysis

Figure 3 shows the structuring process of qualitative content analysis that is used in this research. This research employs a data collection technique. Questionnaire technique is used to collect expert validation data on the product. Expert validators are from pedagogical expert and chemistry concept experts, they are a chemistry teacher and two lecturers from chemistry education field. To collect the data, this research uses a questionnaire sheet for content validation. Data collected is analyzed qualitatively. Qualitative analysis is aimed to process data from questionnaire sheets and summarize the data into descriptive information.

Result and Discussion

Material Collection

Materials from various credible sources are collected from news articles as an example for real phenomenon and journal articles. Sixteen pieces of literature were collected for further analysis. Codes A1 is used to indicate news articles and B1-B16 are used to indicate journal articles. The materials collected in table 1 display author, title, year, and code.

Table 1. The Sources of Collected Materials

Author	Title	Year	Code
Irawan, D	Produksi Minyak Jelantah di Indonesia Mencapai 1,2 Juta Kiloliter	2023	A1
Foo, W. H., Chia, W. Y., Tang, D. Y. Y., Koay, S. S. N., Lim, S. S., & Chew, K. W.	The Conundrum of Waste Cooking Oil: Transforming Hazard into Energy	2021	B1
Mannu, A., Vlahopoulou, G., Urgeghe, P., Ferro, M., Del Caro, A., Taras, A., ... & Petretto, G. L.	Variation Of the Chemical Composition of Waste Cooking Oils Upon Bentonite Filtration	2019	B2
Asli, H., Ahmadinia, E., Zargar, M., & Karim, M. R.	Investigation On Physical Properties of Waste Cooking Oil–Rejuvenated Bitumen Binder	2012	B3
Aniokete, T., Ozonoh, M., & Daramola, M. O.	Synthesis Of Pure and High Surface Area Sodalite Catalyst from Waste Industrial Brine and Coal Fly Ash for Conversion of Waste Cooking Oil (WCO) To Biodiesel	2019	B4
A. N. Phan and T. M. Phan	Biodiesel Production from Waste Cooking Oils	2008	B5
Y.-P. Peng, K. T. T. Amesho, C.-E. Chen, S.-R. Jhang, F.-C. Chou, and Y.-C. Lin	Optimization Of Biodiesel Production from Waste Cooking Oil Using Waste Eggshell as A Base Catalyst Under a Microwave Heating System	2018	B6
Mannu, A., Garroni, S., Ibanez Porras, J., & Mele, A.	Available Technologies and Materials for Waste Cooking Oil Recycling	2020	B7
Awogbemi, O., Von Kallon, D. V., Aigbodion, V. S., & Panda, S	Advances in biotechnological applications of waste cooking oil	2021	B8
Mahmudah, R. A., & Shofiah, N	From waste to wealth: A novel approach for empowering society through recycling used cooking oil into soap.	2023	B9
Félix, S., Araújo, J., Pires, A. M., & Sousa, A. C.	Soap production: A green prospective	2017	B10
Mustakim, Rahmad Taufik, Trismawati	The Utilization of Waste Cooking Oil as A Raw Material of Soap	2020	B11
Hadiah, F., Meliasari, T., & Heryanto, H.	Pemurnian Minyak Jelantah dengan Menggunakan Adsorben Serbuk Biji Kelor Tanpa Karbonisasi dan Bentonit	2020	B12
Rahayu, S., Pambudi, K. A., Afifah, A., Fitriani, S. R., Tasyari, S., Zaki, M., & Djamahar, R.	Environmentally safe technology with the conversion of used cooking oil into soap.	2021	B13

Author	Title	Year	Code
Arlofa N., Budi B. S., Abdillah M., Firmansyah W.	Pembuatan Sabun Mandi Padat dari Minyak Jelantah	2021	B14
Walelu Mwamba B, Sarpong Brobbey M, Leodolff B, Peters S, Mbella Teke G, Mapholi Z.	Techno-economic evaluation of soap production from waste cooking oil with additives derived from citrus peel waste	2024	B15
Azme S. N. K.Yusoff N. S. I. M.Chin L. Y.Mohd Y.Hamid R. D.Jalil M. N.Zaki H. M.Saleh S. H.Ahmat N.Manan M. A. F. A.Yury N.Hum N. N. F.Latif F. A.Zain Z. M.	Recycling waste cooking oil into soap: Knowledge transfer through community service learning	2023	B16
Hartini S, Fiantika Y, Widharto Y, Hisjam M.	Optimal treatment combination for dishwashing liquid soap based on waste cooking oil according to the requirement of indonesian quality standards	2021	B17

Descriptive Analysis

In this stage, materials that are obtained from literature sources are carried out to descriptive analysis. The results of the analysis descriptive described in Table 2.

Table 2. The Results of Analysis Descriptive

Content	Analysis
The Phenomenon of Waste Cooking Oil	In article written by Irawan (2023) [A1] define WCO potential in Indonesia described by TRACTion Energy Asia researcher, Refina Muthia in Gelar Wicara Inovasi Transisi Energi dengan Minyak Jelantah event. According to Badan Pusat Statistik (BPS), WCO consumption in Indonesia has increased 2.32% each year in household area from 2015 to 2020. The result of study about potential availability of WCO in several areas in Indonesia, such as Jabodetabek, Bandung, Semarang, Surakarta, Surabaya, dan Denpasar shows WCO production reaches 204.231 kiloliters each year generated from households and micro business, if extrapolated nationally, potential availability of WCO attain 1.2 million each year derived from frying activity. WCO is one of the hazardous wastes that can cause environmental and human health problems if it disposes inappropriately. For instance, WCO can clogged drains and sewers along with soil and water pollution (Foo et al., 2021) [B1]. This caused by WCO that disposed improperly through water drainage and contaminated water, including sea and groundwater (Foo et al., 2021) [B1]. The layer of oil that covers the water surface precipitate negative impact because of physical, biological, and chemical reactions of the oil. The spreading oil on the water surface will lead to oxidation and photochemical reactions take place. Moreover, deposition of oil at the bottom of sea cause destruction of aquatic life. Furthermore, WCO disposal through landfill will cause soil pollution and affect human health as the waste oil percolate into soil, carried by ground water and will contaminate the source of drinking water for human (Foo et al., 2021) [B1].
Composition of Waste Cooking Oil	Chemical compound in WCO are triacylglycerol, glycerol, free fatty acid (FFA), and several polymerization compounds as well as other impurity from the Maillard process (Mannu et al., 2019) [B2]. According to chemical test result, the major chemical compounds in WCO are oleic acid (43.67%), palmitic acid (38.35%), and linoleic acid (11.39%) (Asli et al., 2012) [B3]. Aniokete et al. (2019) [B4] describe the comparison of chemical composition of WCO to several studies:

Compositions	Ref. [B5]	Ref. [B6]	Ref. [B4]
			Total
Palmitic acid (wt. %)	8.5	34.8	35.64
Stearic acid (wt. %)	3.1	7.90	2.05
Oleic acid (wt. %)	21.2	53.30	45.10
Linoleic acid (wt. %)	55.2	4.00	0.17
Linolenic acid (wt. %)	5.9	-	1.63
Others (wt. %)	4.2	-	14.41

Content	Analysis
Utilization of Waste Cooking Oil	Waste cooking oil (WCO) can be utilized as fuel (biodiesel) and soap (Mannu et al., 2020) [B7] and aromatic candle (Awogbemi et al., 2021) [B8]. To minimize the negative impact of waste cooking oil on the environment, WCO is getting recycled and utilized with any biotechnological application to form several bioproducts (Awogbemi et al., 2021) [B8]. That activity contributes to cost reduction, domestic energy supply secured, materials utilization as well as produce less CO_2. According to several studies in Awogbemi et al. (2021) [B8] WCO is a viable, sustainable, and cost-effective option as a feedstock for bioproducts, such as biodiesel, soap, aromateraphy candle. Moreover, the advanced

Content	Analysis
	WCO conversion by biotechnological application as feedstock for the synthesis of plasticizer, surfactant, and asphalt rejuvenator.
The Soap Making Process with WCO	1. The Purification Process of Waste Cooking Oil In Fitri Hadiah et al. (2020) [B12] the best result of WCO purification shows bentonite as its adsorbent with 120 minutes duration rather than combination of moringa seeds or moringa seeds only. In Rahayu et al. (2021) [B13] and Arlofa et al. (2021) [B14] use carbon active as adsorbent to purify WCO as well. 2. Saponification Process Chemically, soap is salt from free fatty acid. Traditionally, soap is made from reaction between fat or oil with base (NaOH or KOH), the reaction called saponification (Rahayu et al., 2021) [B13]. The addition of base should be gradually while mixing and heated to form a perfect soap (Rahayu et al., 2021). Steps to make soap from waste cooking oil in Arlofa et al. (2021) [B14] are (1) purified waste cooking oil be heated at temperature 55°C; (2) 40% NaOH solution heated at temperature 55°C in different container; (3) Mix them together with 1:2 ratio (NaOH 40% : purified WCO); (4) Add slowly and heat it on hotplate until the temperature raise to 60°C for 45 minutes until thicken; (5) put the mixture into mold and leave it for 2 days until it become solid.
The Benefit of WCO Utilization into Soap	Conversion of WCO into bioproducts such as soap contributes to the efforts towards achieving Sustainable Development Goals (SDGs) along with clean water and sanitation, affordable and clean energy, prevention of pollution of aquatic and terrestrial habitats, climate action and sustainable cities and communities (Awogbemi et al., 2021) [B8]. Waste cooking oil has a potential as a raw material for soap bar (Mahmudah & Shofiah, 2023) [B9]. The use of WCO for soap contributes to reduce environmental or human health problems caused by WCO disposal improperly (Félix et al., 2017) [B10]; (Mahmudah & Shofiah, 2023) [B9]. Additionally, soap production from WCO will promote to the advancement of environmental awareness and scientific literacy (Félix et al., 2017) [B10]. The soap making process can be an activity to boost creativity and entrepreneurial among community (Mahmudah & Shofiah, 2023) [B9]. The production of soap with WCO costs around Rp500 – Rp1.500 for each soap (Félix et al., 2017) [B10]; (Mustakim et al., 2020) [B11]. The study in Hartini et al. (2021) [B17] conducted economic feasibility analysis in soap production with WCO, it provides benefit to economic aspect. The soap produced can be sold at a price Rp8,966 with 5% profit (Hartini et al., 2021) [B17]. Mustakim et al. (2020) [B11] calculate the basic cost production is Rp578 and sold around Rp1,000 and made a profit around Rp9,498,061 in 4 years and the payback period is 0.9 months. Soap production from WCO describe following benefits: (1) WCO and soap were used daily in a household, so utilizing WCO into soap can create a sustainable way of recycling; (2) Using WCO as material for soap is more simple and could be a cost-effective than using WCO as material for any bioproducts, such as biodiesel or bio-lubricants; (3) Soap production from WCO increase social impact because soap is needed for sanitation and hygiene (Walelu Mwamba et al., 2024) [B15]. Furthermore, soap making process is very simple and easily transferable which potential to generate new income through business or employment opportunities (Azme et al., 2023) [B16] and profitable process (Walelu Mwamba et al., 2024) [B15].

Category Selection

In this stage, the arrangement of category is generated based on the results of the previous stage. The purpose of the arrangement is to determine the pattern of relationships and interactions of each component involved. The result from the previous stage it is categorized into five categories, consisting of: (1) The Phenomenon of Waste Cooking Oil, this section describe the potential presence of waste cooking oil in Indonesia and its impact on environmental and human aspects; (2) Composition of Waste Cooking Oil, in this section shows chemical compound contain in WCO; (3) Utilization of Waste Cooking Oil, this section explain the potential utilization of waste cooking oil for any products and the reason why WCO should be utilized to soap; (4) The Soap Making Process with WCO, at this section shows several steps to make soap with waste cooking oil; (5) The Benefit of WCO Utilization into Soap, at this section describe the benefits of soap making with WCO in terms of social, economic, and environmental aspects' and its relation to Sustainable Development Goals (SDGs).

Material Evaluation

Concepts that have been collected from previous stages are described into teaching-learning sequences (TLS).

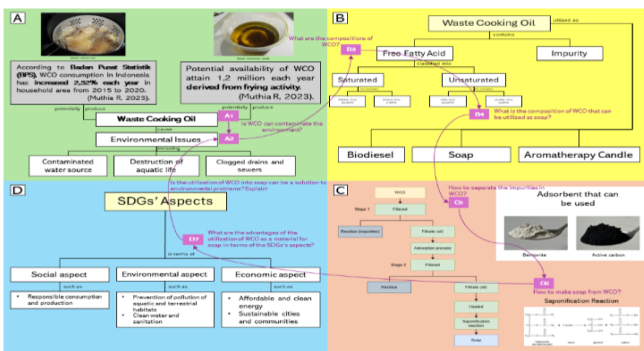

Figure 4. The Teaching-Learning Sequences of Soap Making Project with WCO

The result of the TLS can be seen in Figure 4. On the TLS we categorized each section into A, B, C and D. Section A describe the potential availability of WCO and environmental issues caused by WCO. Section B describe the chemical compounds of WCO and possible utilization products of WCO. Section C describe the process of soap making with WCO. Section D describe the SDGs' aspects in terms of social, environmental, economic aspects. Each section consists of questions referring to another topic between each category marked by number in small squares. The 7 small squares connected by lines to understand the context of the utilization of waste cooking oil, which form a cycle that indicates each section has relationships between concepts. In section A to connect squares A1 and A2, starting with a question: "Is WCO can contaminate the environment?" to connect the topic of the presence of WCO between environmental issues. Next question related to sections A and B with a question connected by squares A2 to B3: "What are the composition of WCO?" as the question for students to research the chemical composition of WCO. In section B, a question to connect squares B3 and B4: "What is the composition of WCO that can be utilized as soap?". Next, in section C, a question related to sections B and C connected by squares B4 and C5: "How to separate the impurities in WCO?". In the same section, a question to connect squares C5 and C6: "How to make soap from WCO?". In D section, a question related to sections C and D connected by squares C6 and D7: "What are the advantages of the utilization of WCO as a material for soap in terms of the SDGs' aspects?". Finally, section D related to section A with a question to connect squares D7 and A2: "Is the utilization of WCO into soap can be a solution to environmental problems? Explain!". The relationship between squares and questions are summarized in Table 3.

Table 3. Questions on the Teaching-Learning Sequences

Relationship between Squares	Questions
A1 and A2	Is WCO can contaminate the environment?
A2 and B3	What are the compositions of WCO?
B3 and B4	What is the composition of WCO that can be utilized as soap?
B4 and C5	How to separate the impurities in WCO?
C5 and C6	How to make soap from WCO?
C6 and D7	How to make soap from WCO?
D7 and A2	Is the utilization of WCO into soap can be a solution to environmental problems? Explain!

The teaching-learning sequences are obtained from the result of studies from various journals article that link concepts from each journal about the context of soap production with waste cooking oil. The result of TLS derived from literature review obtained a relationship between each section and the relationship between lines in squares A1 to D7.

Validation by experts is conducted on the result of the teaching-learning sequences. The validator stated that the teaching-learning sequences are suitable for learning activity. The minor revisions were suggested by validators including the colors indicate numbers must be contrast, the shape of the arrow in each section, and correcting some spelling and the position of the diagram as well.

Conclusion

This study uses qualitative content analysis as a research method to construct teaching-learning sequences (TLS). The teaching-learning sequences are divided into four sections including: (A) The Phenomenon of Waste Cooking Oil, (B) The Composition of Waste Cooking Oil and The Utilization of Waste Cooking Oil, (C) The Soap Making Process with WCO, and (D) The Benefit of WCO Utilization into Soap. The result of TLS on this study can be adapted for learning activity in the context of the utilization of waste cooking oil into soap with project-based learning as its model and can be useful for developing a learning design or teaching materials.

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Author Contributions

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Conflicts of Interest

The authors declare no conflict of interest.

References

Abera, B. H., Diro, A., & Beyene, T. T. (2023). The synergistic effect of waste cooking oil and endod (Phytolacca dodecandra) on the production of high-grade laundry soap. *Heliyon*, *9*(6). https://doi.org/10.1016/j.heliyon.2023.e16889

Aniokete, T. C., Ozonoh, M., & Daramola, M. O. (2019). Synthesis of pure and high surface area sodalite catalyst from waste industrial brine and coal fly ash for conversion of waste cooking oil (WCO) to biodiesel. *International Journal of Renewable Energy Research*, *9*(4). https://doi.org/10.20508/ijrer.v9i4.9621.g7796

Arlofa, N., Budi, B. S., Abdillah, M., & Firmansyah, W. (2021). Pembuatan Sabun Mandi Padat dari Minyak Jelantah. *Jurnal Chemtech*, *7*(1).

Asli, H., Ahmadinia, E., Zargar, M., & Karim, M. R. (2012). Investigation on physical properties of waste cooking oil - Rejuvenated bitumen binder. *Construction and Building Materials*, *37*. https://doi.org/10.1016/j.conbuildmat.2012.07.042

Awogbemi, O., Kallon, D. V. Von, Aigbodion, V. S., & Panda, S. (2021). Advances in biotechnological applications of waste cooking oil. *Case Studies in Chemical and Environmental Engineering*, *4*. https://doi.org/10.1016/j.cscee.2021.100158

Azme, S. N. K., Yusoff, N. S. I. M., Chin, L. Y., Mohd, Y., Hamid, R. D., Jalil, M. N., Zaki, H. M., Saleh, S. H., Ahmat, N., Manan, M. A. F. A., Yury, N., Hum, N. N. F., Latif, F. A., & Zain, Z. M. (2023). Recycling waste cooking oil into soap: Knowledge transfer through community service learning. *Cleaner Waste Systems*, *4*. https://doi.org/10.1016/j.clwas.2023.100084

Félix, S., Araújo, J., Pires, A. M., & Sousa, A. C. (2017). Soap production: A green prospective. *Waste Management*, *66*. https://doi.org/10.1016/j.wasman.2017.04.036

Fitri Hadiah, Meliasari, T., & Heryanto. (2020). Pemurnian minyak jelantah dengan menggunakan adsorben serbuk biji kelor tanpa karbonisasi dan bentonit. *Jurnal Teknik Kimia*, *26*(1). https://doi.org/10.36706/jtk.v26i1.439

Foo, W. H., Chia, W. Y., Tang, D. Y. Y., Koay, S. S. N., Lim, S. S., & Chew, K. W. (2021). The conundrum of waste cooking oil: Transforming hazard into energy. *Journal of Hazardous Materials*, *417*. https://doi.org/10.1016/j.jhazmat.2021.126129

Fourniyati, I. R., Nuswowati, M., & Cahyono, E. (2020). The Effects of Projects Based Chemistry Learning Model, Assisted by Chemsong Video to Students's Learning Completeness and Creativity. *Journal of Innovative Science Education*, *9*(3). https://doi.org/10.15294/jise.v9i1.36750

Guisasola, J., Zuza, K., Ametller, J., & Gutierrez-Berraondo, J. (2017). Evaluating and redesigning teaching learning sequences at the introductory physics level. *Physical Review Physics Education Research*, *13*(2). https://doi.org/10.1103/PhysRevPhysEducRes.13.020139

Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. *International Journal of Educational Research*, *102*. https://doi.org/10.1016/j.ijer.2020.101586

Hartini, S., Fiantika, Y., Widharto, Y., & Hisjam, M. (2021). Optimal treatment combination for dishwashing liquid soap based on waste cooking oil according to the requirement of indonesian quality standards. *Evergreen*, *8*(2), 492–498. https://doi.org/10.5109/4480734

Ijirana, Aminah, S., Supriadi, & Magfirah. (2022). Critical Thinking Skills Of Chemistry Education Students In Team Project-Based Stem-Metacognitive Skills Learning During The Covid-19 Pandemic. *Journal of Technology and Science Education*, *12*(2). https://doi.org/10.3926/jotse.1697

Kemendikbudristek. (2021). *Panduan Pengembangan Projek Penguatan Profil Pelajar Pancasila*. Pusat Asesment dan Pembelajaran, Badan Penelitian dan Pengembangan dan Perbukuan, Kementrian Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia.

Kristiana, T., Baldino, C., & Searle, S. (2022). An estimate of current collection and potential collection of used cooking oil from major Asian exporting countries. *International Council on Clean Transportation*, *2022*(February).

Li, W., Guan, R., Yuan, X., Wang, H., Zheng, S., Liu, L., & Chen, X. (2020). Product Soap from Waste Cooking Oil. *IOP Conference Series: Earth and Environmental Science*, *510*(4). https://doi.org/10.1088/1755-1315/510/4/042038

Mahmudah, R., & Shofiah, N. (2023). From waste to wealth: A novel approach for empowering society through recycling used cooking oil into soap. *Journal of Community Service and Empowerment*, *4*(2). https://doi.org/10.22219/jcse.v4i2.25816

Mannu, A., Garroni, S., Porras, J. I., & Mele, A. (2020). Available technologies and materials for waste cooking oil recycling. In *Processes* (Vol. 8, Issue 3). https://doi.org/10.3390/PR8030366

Mannu, A., Vlahopoulou, G., Urgeghe, P., Ferro, M., Del Caro, A., Taras, A., Garroni, S., Rourke, J. P., Cabizza, R., & Petretto, G. L. (2019). Variation of the chemical composition ofwaste cooking oils upon bentonite filtration. *Resources*, *8*(2). https://doi.org/10.3390/resources8020108

Maotsela, T., Danha, G., & Muzenda, E. (2019). Utilization of waste cooking oil and tallow for production of toilet "bath" soap. *Procedia Manufacturing*, *35*. https://doi.org/10.1016/j.promfg.2019.07.008

Masbukhin, F. A. A. M., Sandra Sukmaning Adji, & Ayu Fahimah Diniyah Wathi. (2023). Project-Based

Learning (PjBL) Model in Chemistry Learning: Students' Perceptions. *European Journal of Education and Pedagogy*, *4*(1). https://doi.org/10.24018/ejedu.2023.4.1.567

Mayring, P. (2000). *Qualitative Content Analysis*. http://www.zuma-mannheim.de/research/en/methods/textanalysis/

Mustakim, M., Taufik, R., & Trismawati, T. (2020). The Utilization of Waste Cooking Oil As a Material of Soap. *Journal of Development Research*, *4*(2), 86–91. https://doi.org/10.28926/jdr.v4i2.114

Psillos D, & Kariotoglou P. (2016). *Iterative Design of Teaching-Learning Sequences Introducing the Science of Materials in European Schools*.

Rahayu, S., Pambudi, K. A., Afifah, A., Fitriani, S. R., Tasyari, S., Zaki, M., & Djamahar, R. (2021). Environmentally safe technology with the conversion of used cooking oil into soap. *Journal of Physics: Conference Series*, *1869*(1). https://doi.org/10.1088/1742-6596/1869/1/012044

Rasman, M., Hassan, N. A., Hainin, M. R., Putra Jaya, R., Haryati, Y., Shukry, N. A. M., Abdullah, M. E., & Kamaruddin, N. H. M. (2018). Engineering properties of bitumen modified with bio-oil. *MATEC Web of Conferences*, *250*. https://doi.org/10.1051/matecconf/201825002003

Situmorang, M., Sinaga, M., Sitorus, M., & Sudrajat, A. (2022). Implementation of Project-based Learning Innovation to Develop Students' Critical Thinking Skills as a Strategy to Achieve Analytical Chemistry Competencies. *Indian Journal of Pharmaceutical Education and Research*, *56*(1). https://doi.org/10.5530/ijper.56.1s.41

Sumarni, W., & Kadarwati, S. (2020). Ethno-stem project-based learning: Its impact to critical and creative thinking skills. *Jurnal Pendidikan IPA Indonesia*, *9*(1). https://doi.org/10.15294/jpii.v9i1.21754

Walelu Mwamba, B., Sarpong Brobbey, M., Leodolff, B., Peters, S., Mbella Teke, G., & Mapholi, Z. (2024). *Techno-economic evaluation of soap production from waste cooking oil with additives derived from citrus peel waste*. https://doi.org/10.21203/rs.3.rs-4017927/v1