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UTILIZATION OF PALM WASTE CHARCOAL BRIQUETTES (ABLS) AS THEMATIC-BASED INTEGRATED SCIENCE LEARNING MATERIALS FOR MIDDLE SCHOOL STUDENTS

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ABSTRACT

This investigation was conducted with the objective of evaluating the efficacy of ABLS ignition and formulating instructional materials for junior high school science education through the integration of e-booklets containing thematic-based science content. The research design employed herein adheres to the principles of experimentation and model development, falling under the category of Research and Development (R&D). The experimental cohort was stratified into three groups denoted as A1 (70% shell charcoal: 30% bunch charcoal), A2 (50% shell charcoal: 50% bunch charcoal), and A3 (30% shell charcoal: 70% bunch charcoal). The development of science learning materials was realized through integration with cobwebs, and subsequently, these materials were formatted into e-booklets. The outcomes of the ABLS ignition quality assessment revealed that composition A1 exhibited the optimal ignition proficiency, requiring 14 minutes to achieve the boiling of 100 ml of water, followed by composition A2 (16 minutes) and A3 (18 minutes). Subsequent ABLS testing, specifically ash analysis, yielded values of 6 grams for A1, 7 grams for A2, and 8 grams for A3. The flame coloration in compositions A1 and A2 manifested as bluish-red, devoid of smoke, whereas A3 displayed a red flame with minimal smoke emission. In conclusion, the ABLS ignition quality test substantiates that a charcoal composition ratio of 70% shell charcoal to 30% bunch charcoal yields the most favorable results. The thematic framework for junior high school science education, centered around the ABLS theme, encompasses six key topics: Classification of Material and Its Changes, Temperature and Changes, Energy and Living Systems, Environmental Pollution, Substance Pressure and Its Application in Daily, and Environmentally Friendly Technology. This study affirms that the ABLS theme holds potential for development into a cohesive thematic model for natural science teaching materials in junior high schools.

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INTRODUCTION

The oil palm (*Elaeis guineensis*) stands as a pivotal industrial crop, contributing significantly to the production of culinary, industrial, and biodiesel fuels. Bengkulu Province emerges as a notable producer of palm oil by-products, owing to the prevalence of oil palm cultivation among its populace, expansive agricultural holdings, and a confluence of industrial facilities engaged in crude palm oil (CPO) production. Comprehensive data spanning the years 2017 to 2019 underscores a discernible uptrend in both the expanse and output of oil palm in Bengkulu Province. Notably, the cultivated area expanded from 205,983 hectares in 2017 to 208,627.11 hectares in 2019, accompanied by a production escalation from 725,949 tonnes in 2017 to 738,377 tonnes in 2019, indicative of a heightened proclivity among farmers to engage in oil palm cultivation (Feni & Marwan, 2023). Concomitant with this trajectory, the quantity of palm oil waste generated by milling activities is anticipated to persistently rise in tandem with escalating oil palm production rates. Traditionally repurposed as a plant fertilizer, particularly within the realm of oil palm cultivation, this residual biomass holds the potential to serve as a pivotal constituent in the fabrication of charcoal briquettes, owing to its inherent biomass energy content.

Briquette charcoal represents a solid fuel paradigm integral to mitigating the escalating demand for fossil fuels, which are undergoing depletion. These briquettes, defined as compact blocks designed for combustion to initiate and sustain a flame, primarily consist of charcoal. Commonly employed variants include coal briquettes, charcoal briquettes, peat briquettes, and biomass briquettes. A noteworthy aspect of briquette production lies in its reliance on raw materials derived from agricultural waste, thereby offering a sustainable solution to energy needs. The integration of biomass energy within briquettes serves as a viable alternative to the progressively diminishing reservoirs of oil and natural gas. This transition is underpinned by the economic viability and uncomplicated technology associated with briquette manufacturing, facilitated by the utilization of cost-effective raw materials. Agricultural residues, including coconut shells, sawdust, straw, and dry leaf waste, emerge as prime constituents for briquette production, as articulated by Onukak et al. (2017). In essence, the utilization of agricultural waste in the creation of briquettes not only addresses the depletion of conventional energy sources but also aligns with a sustainable and accessible approach to meeting energy demands.

In this investigation, the charcoal briquettes under examination were crafted from palm shells and palm fruit bunches, employing tapioca flour as a binding agent. The selection of tapioca flour as an adhesive is rooted in its distinguished attributes of high solution purity, robust gel strength, and superior adhesion properties, rendering it a widely acknowledged adhesive in various applications (Faizal et al., 2014). The deliberate incorporation of diverse compositions in the briquette manufacturing process aims to elucidate the combustion soundness of the resultant briquettes. The production apparatus utilized in the fabrication of these briquettes encompasses a range of specialized tools. These include authoring machines, charcoal grinding machines, mixing machines, charcoal briquette printing machines, scales, knives, sieves, and trays. The multifaceted deployment of these tools ensures precision and efficiency throughout the manufacturing process, contributing to the realization of high-quality charcoal briquettes. This meticulous approach not only underscores the scientific rigor applied in the study but also emphasizes the significance of employing advanced technology and equipment in the pursuit of sound and reliable research outcomes.

The production of charcoal briquettes is a meticulous, scientifically grounded process comprised of six integral stages. Initiated with the preparatory phase, due consideration is given to the systematic organization of tools and materials requisite for subsequent phases. The subsequent charring stage is executed with precision, subjecting the raw material to controlled pyrolysis within a manual charcoal vat to effectuate a transformative process yielding charcoal. Following charring, the refining phase involves grinding the charcoal into a finely powdered state, colloquially referred to as charcoal flour. The ensuing mixing stage is characterized by the deliberate combination of charcoal flour with an auxiliary adhesive, commonly tapioca flour, aimed at augmenting cohesion. The printing phase entails the application of discerning pressure to the amalgamated charcoal flour and adhesive, yielding briquettes of heightened density. The final stage is characterized by the judicious drying of the printed charcoal briquettes, strategically orchestrated to mitigate water content introduced during the material blending process. Upon completion of this meticulous six-stage progression, the resultant charcoal briquettes emerge as efficacious alternatives to conventional fuels, including wood, kerosene, and liquefied petroleum gas (LPG). The deliberate adherence to scientific precision and methodical execution throughout these stages underscores the commitment to producing high-quality charcoal briquettes for discerning applications in energy substitution.

The assessment of charcoal briquette ignition quality entails subjecting the briquettes to controlled combustion over an open flame. The evaluation procedure involves measuring the duration from the initiation of briquette ignition until the point at which the water attains boiling temperature. This specific timeframe is calculated commencing from the moment the briquettes commence burning until the water achieves a temperature of 100 °C, following the placement of the container on the heat source (Purwati & Nurhatika, 2016). The determination of briquette charcoal ignition quality is, therefore, contingent upon the efficiency with which the briquettes facilitate water boiling. A quantitative analysis of the time required to achieve this benchmark provides a metric for discerning the ignition quality, with shorter durations indicative of superior performance. Furthermore, qualitative aspects of briquette ignition, such as flame coloration and smoke emission characteristics, contribute additional dimensions to the overall assessment of ignition quality, elucidating the efficacy and environmental impact of the combustion process.

Efficient management of charcoal briquettes not only mitigates environmental pollution resulting from waste but also offers a constructive avenue for leveraging them as an alternative source for environmentally friendly technological applications that generate alternative energy. The endeavor to treat waste in this manner serves a dual purpose, addressing both environmental concerns and contributing to the development of eco-friendly technological products. This approach aligns seamlessly with educational objectives, presenting an opportunity to enhance students' creativity, innovation, and efficacy. The integration of waste treatment methodologies into educational practices holds significant promise for fostering a skillful learning environment. It necessitates adept efforts in instructional design and delivery to effectively impart the knowledge and skills required for students to engage with waste-to-energy technologies. By incorporating such practices into the educational sphere, students can not only contribute to environmental sustainability but also cultivate essential skills that align with contemporary demands for creative problem-solving and innovation.

The advancement of education is intricately linked to the progress of science and technology. In the contemporary landscape of the 21st century, the ubiquity of instant and global access to information has become a hallmark. Education, as recognized, constitutes a paramount endeavor aimed at nurturing individual potential encompassing religious and spiritual aptitudes, personality traits, self-efficacy, noble character, and skills. This comprehensive development is envisioned to extend beyond the individual to contribute to the well-being of the community, nation, and country at large (Setiawan et al., 2019). Notwithstanding the strides made, persistent challenges continue to impede the seamless evolution of the education system in Indonesia. The complexity of these issues underscores the need for sustained efforts to address and overcome hurdles in order to realize the full potential of education as a transformative force in the nation's development. The synergy between educational reforms and technological advancements remains critical to navigating these challenges and fostering a dynamic educational landscape aligned with the demands of the contemporary era.

Learning constitutes a dynamic process wherein individuals are intentionally engaged in specific contexts to elicit responses from students. Within the educational setting, teaching and learning activities unfold as interactive engagements between educators and students. However, empirical evidence suggests that, in several instances, classroom learning experiences tend to be monotonous and contribute to a waning interest among students, primarily attributed to a teacher-centric approach (Sapari et al., 2015). The efficacy of delivering learning content hinges on two pivotal components: the methodologies employed and the materials used. These components are intricately interconnected, with teaching materials serving as systematically organized subject matter utilized by both teachers and students during the learning process (Purwanto, 2001). The development of teaching materials can leverage the immediate environment, incorporating phenomena such as the utilization of biomass in the form of briquettes as an alternative energy source. Teaching materials, as defined by Arsanti (2018), encompass resources provided for instructional use and management. Teachers are afforded the latitude to prepare an array of teaching materials, including prizes, modules, booklets, logic books, and field guides (Fiqriani et al., 2023). This comprehensive approach underscores the multifaceted nature of effective teaching and learning, which involves not only engaging methodologies but also thoughtfully curated and diverse instructional materials.

Integrated Science stands as a junior high school subject that amalgamates the principles of chemistry, biology, and physics into a cohesive unit. This integration, evolving into what is referred to as integrative science or integrated science (Dewi, 2021), represents a holistic approach to science education. The field grapples with various shortcomings in the learning process, encompassing challenges related to teachers, students, learning facilities, resources, curriculum design, assessment methods, and the overall learning environment (Trianto, 2007). Addressing these challenges, the webbed-type Integrated Science learning model emerges as a noteworthy pedagogical strategy. Among the array of Integrated Science models, the webbed types, three of which are commonly employed, present a user-friendly and practical approach for implementation within the classroom setting. This particular learning model adopts an integrated thematic approach, commencing with the identification of a specific theme that serves as the focal point for subsequent instructional development (Utami et al., 2014). By intertwining the diverse components of chemistry, biology, and physics through a thematic lens, the webbed-type Integrated Science model strives to enhance the coherence and applicability of scientific principles, fostering a more engaging and comprehensive learning experience for students.

Given the outlined considerations, the imperative of a learning design that enhances the meaningfulness of the educational experience becomes evident. The authors of this study aspire to pioneer the development of thematic-based Integrated Science learning materials tailored for junior high school students, integrating the utilization of palm waste charcoal briquettes (ABLS). The overarching goal is to cultivate a dynamic and engaging learning environment. A key innovation of this study lies in the intention to fashion these learning materials into electronic-based teaching resources, specifically in the form of e-booklets. These e-booklets are envisioned to encapsulate instructional content in a manner that is not only visually appealing but also pedagogically effective. The design principles emphasize conciseness, clarity, and the incorporation of abundant visual elements such as images and videos, enhancing the accessibility and comprehensibility of the conveyed material. By infusing technology into the learning process, the study endeavors to harness the advantages of electronic media to create a more interactive and immersive educational experience. This innovative approach aligns with the broader objective of advancing science education through the synthesis of thematic content and contemporary teaching modalities. Ultimately, the anticipated outcome of this study is the creation of electronic-based teaching materials that not only facilitate learning about Integrated Science but also foster a deeper and more impactful educational engagement for junior high school students.

METHOD

The research conducted falls within the realm of experimentation and model development, characterized as Research and Development (R&D). This research model serves the dual purpose of product creation and subsequent efficacy testing. Data collection methods employed encompass experiments, documentation review, and literature study. The data analysis techniques utilized in this study are descriptive and qualitative in nature. Descriptive analysis involves the evaluation of briquette charcoal ignition quality, while qualitative analysis centers on an examination of essential competencies (KD) within the 2013 curriculum's natural science material for junior high school students, specifically as they relate to briquette charcoal.

The charcoal briquettes under investigation are derived from palm waste, namely shells and empty palm oil bunches, with tapioca flour serving as the adhesive. The selection of tapioca flour is informed by its superior adhesion properties compared to other flour types (Nuwa & Prihanika, 2018). The advantages of employing tapioca flour include its ready availability and ease of manufacturing (Tamrin, 2016). The primary tools employed in the study encompass writing machines, charcoal grinding machines, mixing machines, charcoal briquette printing machines, scales, knives, sieves, and trays. The comprehensive process of charcoal briquette production unfolds across six stages: tool and material preparation, authoring, charcoal refinement, ingredient mixing, charcoal briquette molding, and the final drying of the charcoal briquettes. This structured approach aligns with the experimental and model development framework employed in the study, providing a systematic foundation for product creation and assessment.

The assessment of briquette charcoal ignition quality involves the examination of three distinct compositions. Composition A1 comprises 70% palm shell charcoal and 30% palm oil empty bunch charcoal. Composition A2 consists of 50% palm shell charcoal and 50% empty palm oil bunches. Lastly, composition A3 is composed of 30% charcoal shells and 70% empty palm oil bunches. The tools employed for this ignition quality test include digital scales, measuring cups, thermometers, 15 cm pans, stopwatches, bricks, and matches.

The collected data from the results, along with the procedural steps taken, are intended to be crafted into teaching materials. These materials are designed to align with and analyze the science content specified in the 2013 curriculum for junior high school students. The ensuing analysis will involve mapping the obtained results according to the relevant KD outlined in the curriculum. This comprehensive approach not only serves to evaluate the practical aspects of briquette charcoal ignition but also integrates the findings into an educational context. By correlating the results with the curriculum's specified competencies, the study aims to contribute to the development of teaching materials that bridge the gap between practical applications and theoretical knowledge, thereby enhancing the educational experience for junior high school students.

The research on the ignition quality test of briquette charcoal has certain limitations. The primary focus is on specific parameters, including the time required for the briquettes to boil water, the mass of the briquette charcoal used, the color of the flame, and the condition of smoke emitted during ignition. The time calculation for boiling water initiates with the placement of the pot and concludes when the water attains a state of perfect boiling.

However, it's crucial to acknowledge the inherent limitations of this study. The research predominantly centers around data pertaining to briquette charcoal, spanning from the materials utilized in the briquette manufacturing process to the subsequent ignition tests. While these aspects are integral for evaluating the practical efficacy of briquette charcoal, the study's scope is primarily confined to these dimensions. Consequently, the research may not encompass a broader spectrum of factors that could influence the comprehensive understanding of briquette charcoal's utility and performance. It's essential to recognize that the study's focus on these specific aspects aligns with the intent of creating science teaching materials in an integrated manner. The limitations underscore the need for future research endeavors to delve into additional facets of briquette charcoal, providing a more holistic perspective on its potential applications and implications.

RESULTS

The empirical findings derived from the ignition quality test for briquette charcoal constitute a fundamental dataset, providing a substantive groundwork for the formulation of theme-based integrated science teaching materials. These educational resources are designed to encompass a synthesis of critical competencies, denoted as essential competencies (KD). The systematic inventory and exhaustive analysis of these competencies, meticulously aligned with the stipulations of the 2013 curriculum governing science education in junior high schools, are methodically delineated in Table 1. In parallel, Table 2 elucidates the specific outcomes of the aforementioned ignition quality test, thereby serving as a pivotal foundational dataset. This structured approach reflects the methodological rigor applied to the examination of the ignition characteristics of briquette charcoal, and the subsequent integration of these findings into the educational framework underscores a commitment to scientific precision and educational efficacy.

Table 1. Inventory of KD and integrated analysis of natural science material based on the 2013 Curriculum related to principles and concepts ABLS.

KD	Descriptions	Science Concept Material Analysis	ABLS Material-Concept Analysis
3.3	Explain the concepts of mixtures and single substances (elements and compounds), physical and chemical properties, and physical and chemical changes in daily life	1. Classification of matter (state of matter and its composition) 2. Elements, compounds and mixtures	1.1 Solid ABLS form 1.2 ABLS mixture composition 2.1 ABLS chemical element
3.4	Analyze the concept of temperature	1. Definition of temperature 2. Tool to measure temperature (Thermometer)	1.1 Tools and procedures for measuring temperature 1.2 The calorific value affects temperature
3.5	Analyze the concept of energy, various energy sources and changes in energy forms in life	1. Energy sources 2. Change of energy form	1.1 ABLS replacement fuel 1.2 ABLS is a renewable energy source 1.3 ABLS energy transformation
3.9	Analyze the occurrence of environmental pollution and its impact on the ecosystem	1. Various types of waste	1. Utilization of industrial waste as ABLS
3.8	Explain the pressure of matter and its application in life	1. Solid pressure	1. Pressure to form ABLS
3.10	Analyzing environmentally friendly technological processes and products for sustainable living	1. Principles of environmentally friendly technology 2. Friendly technology products in the energy sector	1.1 ABLS applies the principle of environmental preservation 1.2 ABLS facilitates human needs 1.3 ABLS is an environmentally friendly technology product

Table 2. Results of charcoal briquette ignition quality test.

ABLS Type	Volume Water Used (ml)	Time Required to Boil (minutes)	Water Temperature (°C)	ABLS Mass Before Power-Up (gr)	Ash Mass Applied (gr)	Flame Color	Smoke
A1	100	14	100	200	6	Bluish red	None
A2	100	16	100	200	7	Bluish red	None
A3	100	18	100	200	8	Red	Slightly

The intricate interdependence between the constituents of natural science material and the underlying principles of ABLS is metaphorically represented as a spider web in Figure 1. This graphical depiction offers a comprehensive visual representation, elucidating the nuanced interconnectedness inherent in these foundational components. Figure 2 further delineates the initial framework of teaching materials, presenting a curated inventory of ABLS concepts seamlessly integrated within the broader context of Integrated Science materials, all packaged within an e-booklet format.

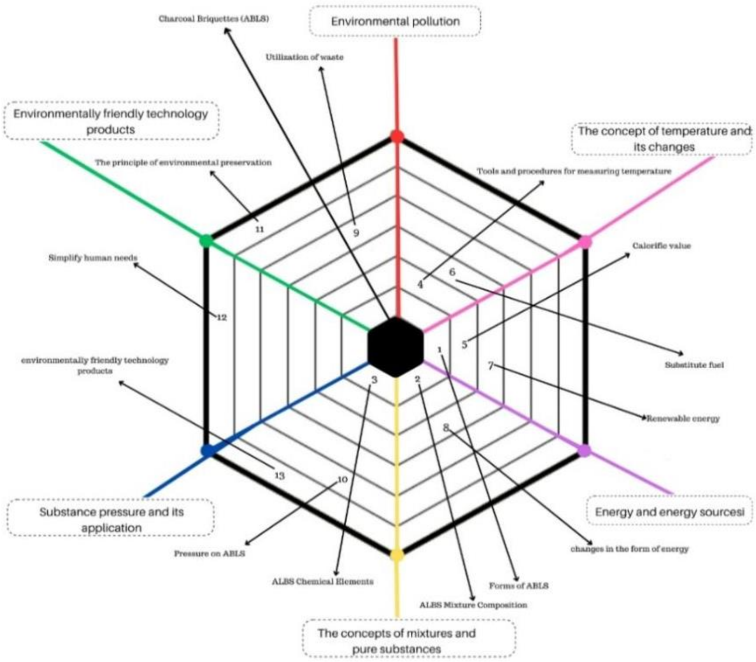

Figure 1. Integrated science learning spider web.

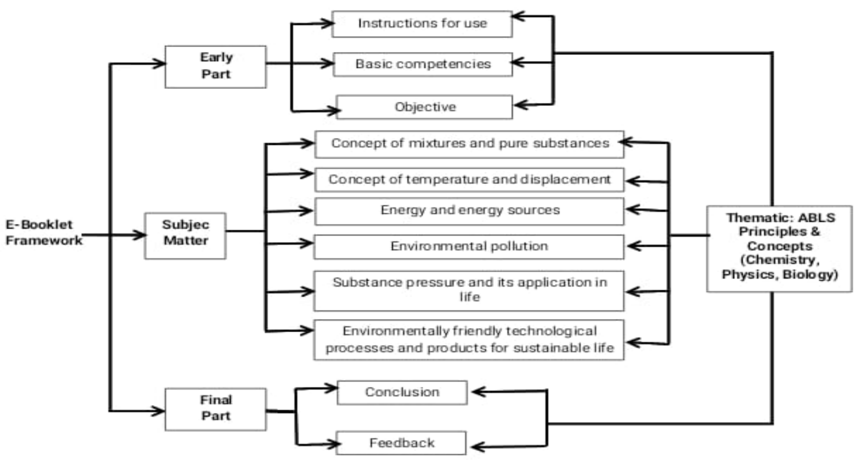

Figure 2. The initial framework of teaching materials in the form of an integrated e-booklet on ABLS.

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

Figure 3. The ABLS e-booklet design model comprises several key components: (a) the cover, (b) an elucidation of the concept of environmentally friendly technology, (c) the provision of general information on charcoal briquettes, and (d) a conclusive section. These components collectively serve as instructive materials tailored for students, specifically focusing on the subject of environmentally friendly technology.

The culmination of these scholarly endeavors finds manifestation in Figure 3, which serves as the graphical representation of the meticulously crafted design model for teaching materials in the form of an e-booklet. This model epitomizes an iterative development process, synthesizing the empirical insights gleaned from the test results, the stipulated curriculum competencies, and the overarching conceptual framework. The result is an integrated and cohesive educational resource, strategically designed to enhance the pedagogical landscape of junior high school science education. This comprehensive and refined approach underscores a commitment to scholarly precision and the efficacy of instructional resources.

DISCUSSION

Briquette charcoal stands as a promising solid fuel alternative, strategically positioned to alleviate the increasing demand for energy in the face of depleting fossil fuel reserves. Derived from residual solid waste generated by palm oil mills, specifically palm shells and empty palm oil bunches, charcoal briquettes represent a sustainable response to the prevailing energy challenges. The intricate manufacturing process of charcoal briquettes encompasses six distinct phases: meticulous preparation of tools and materials, precise composition of raw materials, nuanced refinement of charcoal, meticulous amalgamation of ingredients with the inclusion of tapioca flour as an adhesive, intricate molding of briquettes, and the conclusive phase of systematic drying.

The variants of briquette charcoal earmarked for subsequent ignition quality testing exhibit distinct compositions. Composition A1 entails a precise blend of 70% palm shell charcoal and 30% palm oil empty bunch charcoal. Composition A2 adopts an equilibrium with an equal distribution of 50% palm shell charcoal and 50% empty palm oil bunches. Lastly, composition A3 manifests as a composition comprising 30% charcoal shells and 70% empty palm oil bunches. All briquette charcoal specimens undergo meticulous craftsmanship at the Jajaran Baru LPHD in the Magang Sakti District, Musi Rawas Regency, South Sumatra Province, ensuring a standardized and controlled manufacturing milieu conducive to scientific rigor and reliability.

In the ignition quality test for briquette charcoal, the experimental setup involved the utilization of 100 ml of water, kerosene, and three distinct briquette compositions denoted as A1, A2, and A3, each weighing 200 grams. The requisite equipment for this investigation included digital scales, measuring cups, bricks, a 15 cm saucepan, matches, and a stopwatch. The results of the ignition quality test revealed notable distinctions among the three types of briquettes. A1 charcoal briquettes, comprising a composition of palm shell charcoal and empty palm oil away charcoal in a ratio of 70% to 30%, exhibited a superior performance in boiling water compared to briquette charcoal A2 and A3. The heating process involved the transfer of heat to the water, resulting in a gradual temperature rise until reaching the boiling point. The manifestation of gas bubbles in the water initiated from the bottom of the container, ascending continuously to the top, a characteristic phenomenon associated with boiling, typically occurring at 100 °C (Firmansyah, 2018).

Charcoal briquettes exhibiting commendable ignition quality are exemplified by A1 briquettes, owing to the influential contribution of oil palm shells. Therefore, the heightened incorporation of palm shells in the fabrication of charcoal briquettes correlates positively with improved ignition quality. Palm kernel shells, besides being non-toxic and biodegradable, also present an environmentally advantageous attribute by emitting lesser pollution compared to conventional fuels like gasoline and diesel. Charcoal briquettes, formulated from palm shells, boast a suite of merits, including elevated carbon content, efficient heat generation, standardized dimensions, and facile storage and transportability.

In the context of briquette charcoal quality, factors beyond raw materials also play a pivotal role. The choice of adhesive, as indicated by (Faizal et al., 2014), emerges as a significant determinant. The utilization of tapioca-based adhesive flour is particularly noteworthy, given its cost-effectiveness and reduced smoke and ash production compared to alternative adhesives, as established by Moeksin et al. (2017).

An additional advantage of charcoal briquettes, articulated by Apriyanto et al. (2022), lies in the economic realm. The use of charcoal briquettes presents a cost-effective alternative to liquefied petroleum gas (LPG), whose prices exhibit a consistent upward trajectory. This economic consideration aligns with the overarching advantage of alternative fuels, such as briquettes, as expounded by Setiani et al. (2019). These alternative fuels not only offer cost-effectiveness but also contribute to environmental sustainability, embodying a form of renewable energy.

The quantification of consumed ABLS ash involves computing the disparity between the initial mass of ABLS and the mass of ABLS ash utilized in the water boiling process. It is essential to recognize that in the combustion process of a fuel, only its organic components burn, leaving behind inorganic residues known as ash content (Cholilie & Zuari, 2021). Therefore, a lower quantity of briquette charcoal used signifies a more efficient energy yield from the briquettes. This assertion aligns with the perspective articulated by Biantoro & Widayat (2021), emphasizing that a higher ash content correlates with diminished briquette quality. Specifically, charcoal briquettes characterized by composition A1 exhibit a reduced ash content compared to those with compositions A2 and A3, thus manifesting superior energy production quality. This correlation underscores the importance of ash content as a critical parameter in evaluating the efficacy and performance of briquette charcoal.

The flame coloration resulting from the ignition of briquette charcoal varies among compositions. Specifically, compositions A1 and A2 yield a bluish-red flame color, while composition A3 produces a red flame color. In terms of smoke emission during the ignition quality test, compositions A1 and A2 exhibit a smoke-free characteristic, while composition A3 generates minimal smoke.

These distinctions in flame color and smoke production are attributed to the pyrolysis process, wherein the high temperature plays a pivotal role in influencing ash content, flame color, and smoke conditions. As elucidated by Atmojo (2018), elevated carbonization temperatures contribute to increased carbon production and reduced ash content. Consequently, a higher carbon yield in the pyrolysis process corresponds to a heightened calorific value, mitigating smoke generation and resulting in a bluish flame color. This correlation underscores the intricate relationship between pyrolysis parameters and the observed combustion characteristics of the briquette charcoal compositions.

The inventory and analysis of basic competencies, as outlined in the 2013 curriculum for science education in junior high schools, can be systematically structured into e-booklets for use as comprehensive teaching materials. This analytical process is grounded in the syllabus delineated within the 2013 curriculum, specifically targeting science subjects for grades VII, VIII, and XI. The synthesis of this analysis, particularly pertaining to the ABLS material, facilitates its integration into the domain of natural science material.

An examination of the syllabus reveals a seamless integration of ABLS material into the science curriculum, specifically within the purview of KD 3.3 for class VII. This competency focuses on elucidating the concept of mixtures and single substances (elements and compounds), exploring their physical and chemical properties, and understanding physical and chemical changes in daily life. ABLS aligns with this competency, considering its mass, spatial occupancy, and solid state. The composition of ABLS, encompassing palm shells, empty palm oil bunches, tapioca flour, and water, represents a mixture of distinct ingredients. Furthermore, ABLS encompasses various chemical elements, including carbon (C), hydrogen (H), oxygen (O), and others. This integration underscores the relevance of ABLS within the broader context of foundational science education, fostering a holistic understanding of both physical and chemical principles.

Within the purview of KD 3.4, which entails the analysis of material temperature concepts, ABLS presents itself as a pertinent subject for comprehending temperature phenomena. This inquiry can be effectively conducted through practical applications, such as employing ABLS for water boiling, utilizing requisite instrumentation, and adhering to established procedures for temperature measurement. The discernible heat generated by each instance of ABLS contributes to a nuanced understanding of the thermal properties, specifically the degree of heat (temperature) in this particular context.

Transitioning to KD 3.5, which encompasses the analysis of energy concepts, energy sources, and the metamorphosis of energy forms in daily life, ABLS emerges as a salient material. ABLS demonstrates its efficacy as a substitute for conventional fossil fuels in domestic applications such as gas and kerosene. Positioned as a renewable energy source, ABLS harnesses energy from sustainable natural processes, notably extracting energy from palm oil waste. The metamorphosis of energy forms is manifest in ABLS, where chemical energy undergoes transformation into heat energy due to the inherent presence of chemical elements.

In the realm of KD 3.8, which delves into the analysis of environmental pollution occurrences and their repercussions on ecosystems, industrial waste assumes prominence. When mishandled, industrial waste poses risks to surrounding ecosystems. Optimal waste management becomes imperative for ensuring economic viability and market value. ABLS, originating from waste generated by the palm oil industry, exemplifies a constructive and environmentally beneficial application, concurrently mitigating ecological impact and contributing to economic and commercial value.

The integration of science learning in class VIII aligns with KD 3.8, focusing on elucidating substance pressure and its practical applications in everyday life. Within this context, the material for conveyance centers around the process of crafting charcoal briquettes, necessitating the use of a press to mold the briquettes into cohesive blocks. The applied pressure on ABLS serves the purpose of compacting the entire briquette charcoal mixture. It is crucial to subject ABLS to this pressure to optimize combustion quality, as insufficient pressure could lead to rapid ash formation. This phenomenon occurs when the bonds between compositions lack robustness and fail to adhere adequately. Therefore, the comprehension and application of substance pressure become integral to achieving optimal results in the formation and combustion of ABLS-based charcoal briquettes.

The integration of science learning in class XI can be seamlessly incorporated into KD 3.10, which centers on analyzing environmentally friendly technological processes and products for sustainable living. Within this competency, the material for conveyance involves ABLS, which adheres to the principles of environmental preservation by avoiding the generation of hazardous waste and utilizing materials derived from natural sources. This application underscores the contemporary relevance of ABLS, aligning with current environmental consciousness. Moreover, ABLS facilitates eco-friendly practices by offering a viable alternative for various activities, meeting human needs without resorting to wood as fuel and thereby mitigating deforestation. This not only aligns with environmental preservation but also contributes to the reduction of tree cutting. ABLS serves as an exemplary environmentally friendly technological product, presenting a sustainable solution for everyday life in the energy sector. Its application as an alternative to firewood and a means to decrease reliance on kerosene fuel exemplifies the adaptability and eco-conscious attributes of ABLS in contributing to sustainable living practices.

The intricate interplay between the concepts of natural science material and the principles of ABLS is illustratively represented as a spider web, as depicted above. The webbed-type integrated learning, as exemplified by this visualization, constitutes a learning model that accentuates an integrated organizational pattern, united by a thematic framework. This thematic framework is derived from external subjects but remains aligned with essential competencies and pertinent topics (Armadi & Astuti, 2018; Yusuf & Wulan, 2015). The thematic model, as showcased here, serves as an innovative alternative to the conventional, time-honored pattern of material organization commonly employed in education. This approach emphasizes a more interconnected and thematically driven method of presenting scientific content, thereby fostering a holistic understanding of the subject matter.

Figure 1 illustrates a spider web comprising six webs and six hands, symbolizing the interrelation between science material and the principles of ABLS. Each web represents the science material that can be conveyed based on the ABLS concept, indicated by the number of cobwebs. Concurrently, the six hands signify KD, each holding the material to be conveyed. A total of 13 ABLS concepts are associated with science material for junior high school students, encompassing aspects such as the form of ABLS, ABLS mixture composition, chemical elements in ABLS, tools and procedures for measuring temperature, calorific value, changes in the form of energy, renewable energy sources, utilization of waste (palm oil waste), press on ABLS, the principle of environmental preservation, providing convenience for human needs, and environmentally friendly technology products.

The abundance of webs and hands on the cobwebs signifies the robust connection between science material concepts and ABLS principles, emphasizing their suitability for thematic-based junior high school science learning materials. Thematic learning, defined as an instructional approach that integrates essential competencies and indicators from multiple subject contents into a cohesive theme, is showcased as a pedagogical strategy that provides meaningful experiences. This approach enables students to comprehend concepts more easily by focusing on a singular theme throughout various lessons, fostering a comprehensive understanding (Indriani, 2015; Irawan, 2016; Mulyadin, 2016).

The initial framework of the integrated e-booklet for ABLS comprises three distinct sections: the initial section, the primary material, and the concluding section. The initial segment includes user instructions, essential competencies, and objectives, providing guidance for users. The primary material within this e-booklet encapsulates science content aligned with essential competencies, systematically organized based on the principles and concepts of ABLS. Lastly, the concluding section incorporates conclusions drawn from the ABLS ignition test, along with feedback.

The development of teaching materials is grounded in the ABLS ignition test results, an inventory analysis of natural science material, and the identification of essential concepts across various subject matters. These materials are meticulously structured to present concepts in a systematic manner, guiding students toward the attainment of competency. The e-booklet format ensures a cohesive and comprehensive delivery of content, facilitating an effective and engaging learning experience.

The developed teaching materials take the form of thematic-based e-booklets, encompassing content related to various subject matters. These materials are designed with a focus on essential competencies, learning objectives, and the principles of creating concise, attractive, accessible, and interactive educational content. Referred to as electronic-based teaching materials, this collection systematically conveys comprehensive learning experiences, reflecting the mastery of competency demands by students and presented in an interactive multimedia format (Sriwahyuni et al., 2019). The e-booklets are seamlessly integrated with digital-based learning applications, streamlining the implementation of the learning process (Amalia et al., 2020). Utilizing the Flip PDF and Canva applications, the creation of these teaching materials ensures that the content encapsulates essential concepts in science across various subjects, fostering a rich and engaging learning experience.

The instructional material design model, embodied as an e-booklet, systematically encompasses 18 pages arranged deductively, commencing with an elucidation of the concept of environmentally friendly technology and subsequently delving into comprehensive insights on charcoal briquettes. The e-booklet unveils with a cover bearing the title "Briquets as An Alternative Energy Source," offering crucial insights pertaining to charcoal briquettes. Page (1) initiates with a preface elucidating the essence of the e-booklet, and page (2) furnishes instructions, essential competencies, and indicators to facilitate seamless navigation for students. Pages (3–17) meticulously unfold the environmental-friendly technology material, encompassing (a) exemplification of its applications in the energy sector; (b) the exploitation of biomass from agricultural waste as a foundational component for charcoal briquettes; (c) a comprehensive definition of charcoal briquettes; (d) visual depictions of tools and materials employed in their production and quality evaluation; (e) a video demonstration elucidating the process of crafting charcoal briquettes with three distinct compositions; (f) visual representations of the resultant briquette charcoal; (g) a video exhibition of the quality assessment test for combustion; (h) detailed information regarding the briquettes utilized in the combustion quality evaluation; (i) specifics concerning the density of the fabricated briquette charcoal; (j) an interrogative segment addressing the sequential order of the tested briquette charcoal in terms of combustion quality. Page (18) concludes the e-booklet, encapsulating a synthesis of the intricate interplay between environmentally friendly technology and the realm of charcoal briquettes.

The aspiration for the learning material encapsulated within the e-booklet format is to augment students' comprehension of environmentally friendly technology material, with a particular emphasis on the discourse concerning environmentally friendly technology in the energy sector. This endeavor aligns with the overarching objective of attaining KD 3.10, specifically focusing on the analytical scrutiny of processes and products within environmentally friendly technology for the promotion of sustainable living. The envisaged outcome is an enriched understanding among students, fostering a profound grasp of the pivotal concepts enshrined within the realm of environmentally friendly technology.

CONCLUSION

In summary, this study culminates in the comprehensive inventory and analysis of essential competencies (KD) aligned with the 2013 curriculum for science learning in junior high schools. The identified theme of palm oil waste charcoal briquettes (ABLS) stands poised to evolve into a thematic model for science teaching materials at the junior high school level. The proposed model encompasses six core topics: (1) Classification of Material and Its Changes, (2) Temperature and Changes, (3) Energy and Living Systems, (4) Environmental Pollution, (5) Substance Pressure and Its Application in Daily Life, and (6) Environmentally Friendly Technology. Recommendations stemming from the study advocate for a refined focus in e-booklet design, specifically honing in on environmentally friendly technology and the corresponding KD 3.10, which centers on the analysis of environmentally friendly technological processes and products for sustainable living. This strategic focus is poised to enhance the effectiveness and coherence of teaching materials, paving the way for seamless integration into science education. Future research endeavors are encouraged to delve deeper into the development of teaching materials, specifically exploring the nuanced intricacies of ABLS implementation within the broader context of natural science materials.

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AUTHOR CONTRIBUTIONS

SFN was involved in conceptualizing the research, designing the methodology, carrying out formal analysis and compiling the original manuscript, apart from also contributing to the visualization of the creation of learning media. RWW and BK contribution was to guide, provide criticism and suggestions in preparing the manuscript and provide overall supervision in this research. HJ and DP contributed to the review, provided comments and suggestions, as well as input during the research process. FM and L contributed directly to making briquettes in the field, helping to find data and calculate data.

CONFLICT OF INTEREST STATEMENT

Regarding the research, writing, and publication of this paper, the authors state they have no competing interests.

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