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TECHNO-ECONOMIC FEASIBILITY OF EDUCATIONAL BOARD GAME PRODUCTION FROM AGRO-INDUSTRIAL WASTE IN SUPPORT OF SUSTAINABLE DEVELOPMENT GOALS (SDGS) THROUGH SCIENCE AND TECHNOLOGY INTEGRATION

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Abstract

This study aimed to examine the techno-economic feasibility of producing educational board games using agro-industrial waste, integrating science and technology to support the Sustainable Development Goals (SDGs). A feasibility analysis was conducted over a projected period using parameters such as net present value, profitability, return on investment, and payback time. The project was simulated under contextual economic assumptions relevant to Central Java, Indonesia. The results indicated the project is feasible both financially and technically. This is because the production process utilizes efficient waste management, integrates scientific processing methods, and employs technology-based equipment aligned with environmental and educational objectives. The project contributes to quality education and industrial innovation by transforming sugarcane bagasse into an interactive learning tool that enhances accounting literacy. The impact highlights how science, technology, and sustainability can be integrated to foster educational innovation while promoting environmental responsibility, aligning with SDG 4 and SDG 9.

Keywords Accounting education, Agro-industrial waste, Board game, Science and technology, Sustainable development goals.

1. Introduction

Educational board games have emerged as innovative pedagogical tools that foster active learning, engagement, and conceptual understanding across various disciplines, including accounting [1, 2]. In accounting education, especially among vocational and undergraduate students, abstract principles such as financial recording, cost analysis, and reporting often pose comprehension challenges [3-7].

By incorporating game-based learning strategies, educators can offer students simulated, real-world decision-making experiences that promote collaborative and applied learning [8-13]. Simultaneously, there is increasing global attention on integrating sustainability into education through materials and methods that align with the Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education) and SDG 9 (Industry, Innovation, and Infrastructure) [14].

In response to environmental concerns, agro-industrial waste (particularly sugarcane bagasse) has gained prominence as an alternative raw material in diverse applications such as energy, particleboard, and bioethanol production [15-19]. Indonesia, ranking among the top producers of sugarcane, generates considerable volumes of bagasse, which often go underutilized or contribute to environmental degradation when incinerated [20]. Prior studies regarding the use of sugarcane have been well-documented [21, 22]. One of them examined the mechanical feasibility of using sugarcane bagasse for particleboard and construction materials [23-25], but limited research exists on its integration into educational products, particularly as a sustainable material for interactive learning media in accounting.

This study aims to conduct a techno-economic feasibility analysis of producing an educational accounting board game from sugarcane bagasse waste. The novelty of this work lies in combining science and technology (through material processing, equipment optimization, and economic modelling) with pedagogical innovation to support the SDGs. By leveraging sugarcane bagasse as a renewable material and transforming it into a tool for accounting literacy, this project offers dual value: reducing environmental waste and enhancing educational effectiveness. The integration of scientific procedures (such as pulping and sheet forming) and cost estimation techniques demonstrates how agro-waste can be innovatively processed into functional learning tools. This research fills a gap by evaluating not only the technical aspects but also the economic viability of such an initiative, providing a replicable model that bridges sustainability, education, and industrial innovation. This adds new information regarding feasibility studies as reported elsewhere [26-31].

2. Literature Review

Figure 1 illustrates the production process of the accounting board game made from sugarcane bagasse, which follows standard board manufacturing procedures with modifications in the finishing and printing stages to suit educational content. The process includes shredding and washing the sugarcane bagasse, digesting it with water and sodium carbonate to produce pulp, and then pressing and drying the pulp into sheets. These sheets are further refined to match the desired thickness and dimensions before printing the educational content, thereby transforming agro-industrial waste into functional learning media through scientific and technological procedures [23].

Board games have proven effective in education by enhancing learner motivation, interaction, and conceptual understanding across various fields. Their use in accounting education supports the development of applied competencies, enabling learners to engage in simulated financial decision-making and gain deeper insights into fundamental accounting principles [6, 7]. Studies show that such games improve retention and cognitive engagement when integrated into accounting instruction [8]. This pedagogical method aligns with current efforts to introduce experiential learning strategies in professional and technical education.

The utilization of sugarcane bagasse has been widely explored in industries such as construction, bioenergy, and bioethanol production due to its mechanical strength and environmental advantages. Bagasse-based boards have been validated for their durability and suitability in panel production, further indicating potential for educational applications [20, 24]. Other studies support its use in renewable energy and alternative fuel strategies, confirming its versatility as an industrial input [15, 16]. Despite this, its use in educational innovation remains limited. Recent discourse has highlighted the importance of integrating techno-economic evaluation in sustainable product development to ensure practicality and scalability [32, 33]. This research contributes to filling that gap by combining agro-waste utilization, education technology, and economic analysis, thus addressing science and technology integration in support of the SDGs.

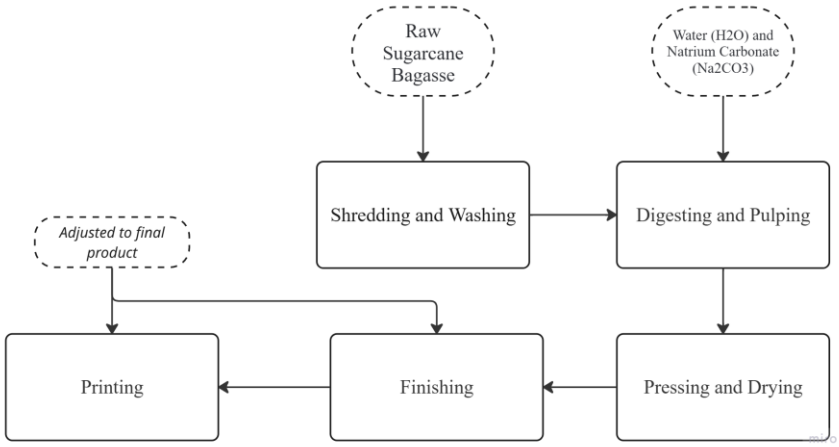

Fig. 1. Creation process of an accounting board game from sugarcane bagasse.

3. Methods

We used calculation for understanding the feasibility study, as reported elsewhere [34]. Table 1 presents the analysis of raw materials required for one production cycle, with sugarcane bagasse as the primary input. This cycle produces approximately thirty-six thousand units of educational board games per day under industrial-scale assumptions. Key materials include sodium carbonate for digestion, natural glue for binding, and biodegradable plastic for packaging. The prices are estimated based on commercial market values relevant to the Central Java region of Indonesia, ensuring the analysis reflects realistic and applicable economic conditions [17].

Table 1. Analysis of raw materials.

No.	Raw material	Large Scale Production Requirements	Unit	Price (USD)	Total (USD)
1	Sugarcane Bagasse	2.000	Kg	0.04	86.07
2	Natrium Carbonate	200	Kg	0.68	135.26
3	Water	10.000	Kg	0.05	4,918.54
4	Ink/Paint Design	500	Kg	4.30	2,151.86
5	Natural Glue	200	Kg	2.46	491.85
6	Plastic/Pack Degradable	50	Kg	0.37	18.44
	Total per production cycle (daily)				**3,375.35**
	Total per production cycle (annually)				**1,012,603.60**

Table 2 details the environmentally friendly equipment used in the production process, selected to align with the sustainability goals of the project. Machinery such as hydrapulpers, sheet formers, drying ovens, and laser cutters are included to ensure technical feasibility while maintaining production efficiency. The inclusion of a medium-scale printing machine also reflects the integration of educational design with industrial manufacturing standards. All equipment prices are benchmarked from commercially available technology to represent valid investment estimates for this feasibility model [33].

Table 2. Prices of environmentally friendly machinery and equipment.

No.	Machine and Equipment	Unit Price (USD)	Amount	Total Price (USD)
1	Hydrapulper (TX-8)	9,222.26	1	9,222.26
2	Sheet former/pulp sheet machine	7,377.80	1	7,377.80
3	Dryrer (Oven Listrik)	2,520.75	1	2,520.75
4	Laser Cutter	860.74	1	860.74
5	Medium Printing Machine	18,444.51	1	18,444.51
	Total			**38,426.06**

This study adopted a techno-economic feasibility approach by simulating a 20-year business projection. Evaluation parameters include Cumulative Net Present Value (CNPV), Return on Investment (ROI), Percent Profit on Sales, and Pay Out Time. These indicators were selected to ensure comprehensive financial and technical assessment of the project. The discount rate applied is fifteen percent annually, and the analysis assumes daily production cycles under full capacity utilization. All cost estimations were converted into USD for standardization, using an exchange rate of 1 USD to 16,292 IDR. Fixed and variable costs, as well as capital expenditures, were calculated based on local and international pricing norms to maintain contextual accuracy [32]. The method integrates scientific, technical, and financial perspectives to project not only profitability but also long-term

sustainability and educational impact. The use of actual process simulations and market-aligned inputs enhances the validity of this model in real-world applications. This approach allows for assessing whether waste-based board game production can be both environmentally responsible and economically viable, while simultaneously addressing educational innovation aligned with the SDGs.

4. Results and Discussion

Table 3 shows the financial assumptions and performance indicators based on projected production and sales of the accounting board game. The model assumes capital-related fixed costs, variable costs including raw materials and labor, and an estimated revenue stream. With sales estimated over a 20-year period, the project yielded a percent profit on sales of 3.32%, return on investment of 3.56, and a payback period within three years. The break-even point was achieved after selling approximately 2.9 million units. These indicators suggest the project is financially feasible under realistic industrial condition.

Table 3. Production cost assumption factors and financial performance.

Component	Parameter	Cost in IDR
Fixed Cost		
	Capital Related Cost	21,049,313,169
	Depreciation	1,835,592,558
	Total Fixed Cost	22,884,905.727
Variable Cost	Raw material	63,744,000,000
	Utilities	2,757,333,810
	Operating Labor (OL)	432,000,000
	Labor Related Cost	129,600,000
	Sales Related Cost	11,550,105,000
	Total Variable Cost	78,613,038,810
% Profit Estimated	Sales	165,001,500,000
	Manufacturing Cost	99,662,351,979
	Investment	19,675,035,772
	Profit	40%
	Profit to Sales	3.32
BEP	Unit	11,000,100
	Fixed Cost	22,884,905,727
	Variable cost	78,613,038,810
	sales	165,001,500,000
	BEP	2,914,003,19
	Percent Profit on Sales	0.395
	Return on Investment	3.559
	Pay Out Time	0.273

Figure 2 depicts the cumulative net present value (CNPV) curve over the projected 20-year timeline. The curve initially declines in the first two years, indicating the capital investment phase, where cash inflows are insufficient to cover costs. However, by year three, the CNPV crosses the breakeven threshold and begins a consistent upward trajectory, reflecting increasing profitability. Growth remains strong through the tenth year and plateaus afterward. This pattern indicates that the investment not only recovers quickly but also yields stable long-term financial returns [32].

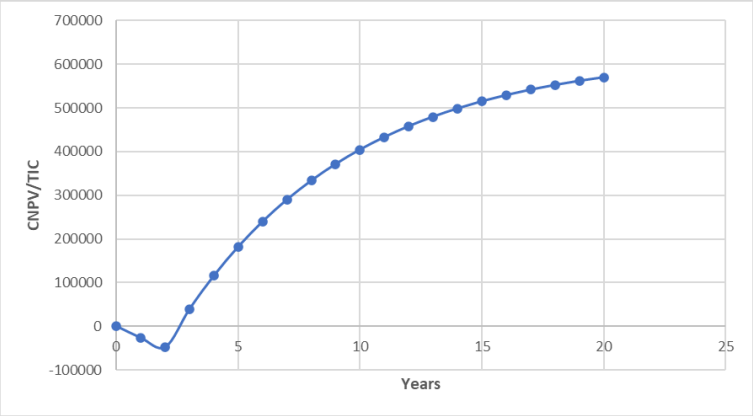

Fig. 2. Ideal lifetime CNPV (years).

The cost structure highlights a well-balanced ratio between fixed and variable expenditures, supported by appropriate capital investment in efficient machinery [33]. The pricing strategy and production efficiency align with manufacturing best practices and educational market demand. From a sustainability standpoint, the use of sugarcane bagasse adds environmental value by reducing biomass waste and supporting material reuse, directly contributing to SDG 12 (Responsible Consumption and Production). Simultaneously, the educational value is preserved through the gamified approach that fosters financial literacy, supporting SDG 4 (Quality Education). This adds new information regarding SDGs as reported elsewhere [35-40].

Moreover, this project integrates scientific techniques such as pulping and drying, combined with modern production equipment, which underscores the role of science and technology in transforming agro-industrial waste into functional educational tools. This aligns with the global emphasis on sustainable innovation that bridges industry and education [6, 16, 20]. By doing so, the project offers a replicable model where waste management, educational technology, and economic feasibility converge.

5. Conclusions

This study confirms the technical and economic feasibility of producing educational board games from agro-industrial waste. By combining science, technology, and sustainability, the project supports SDGs through innovative learning tools, environmental responsibility, and long-term industrial value. Future work should expand to broader implementation and lifecycle analysis.

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