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Developing Eco-Innovative Teaching Materials through Sugarcane Husk-Based Brick Synthesis

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ABSTRACT
The purpose of this study is to develop brick synthesis teaching materials incorporating sugarcane husks, to be used as one of the teaching materials for the ethnoscience and edupreneurship course. The use of sugarcane husks in the brick-making process is very important to introduce to students of ethnoscience and edupreneurship courses because it provides new knowledge that can inspire scientific and economic impact. Clear and practical teaching materials are essential for the course. Therefore, this study uses the 4D model research and development method (Define, Design, Develop, and Disseminate). The technical analysis of quantitative data uses the results of the teaching material validation instrument completed by 4 expert validators, while qualitative data is obtained through a response questionnaire. Based on the study's results, the brick synthesis teaching material with the addition of sugarcane husks was deemed valid, with scores of 3.4 by learning experts, 3.2 by material physicists, and 3.3 by economists. Meanwhile, based on the results of the questionnaire distributed to 100 students, the results showed that 92% of students gave a very good response, which means that this teaching material is practical to use in learning, so it can be concluded that the brick synthesis teaching material with the addition of sugarcane husk is feasible and practical to use in learning.

Keywords: *teaching materials, brick synthesis, sugarcane husk*

INTRODUCTION

Based on data from the Pusat Penelitian Perkebunan Gula Indonesia (P3GI), national sugar production in 2022 reached 2.35 million tons, with a total of around 30 million tons of milled sugarcane. Approximately 9.6 million tons of sugarcane bagasse are produced from the milling process, as bagasse constitutes 32% of the weight of the milled sugarcane. The use of bagasse has increased, with about 70% used as boiler fuel in sugar mills, as raw materials in the paper industry, and as mushroom growth media. However, around 30% of bagasse remains underutilized, thus opening opportunities for innovation in converting this waste into value-added products (Pusat Penelitian Perkebunan Gula Indonesia (P3GI), 2022). Kediri Regency is the second most sugarcane-producing district in East Java Province, with an average annual production of 197,409, indicating that waste from the calling process is also not utilized optimally. In the research area, there are quite a lot of traditional sugar factories in one village area with waste in the form of husks, which are used more as feed, as fuel, and the rest is burned or left alone.

Brick is widely used in building construction for its high strength and resistance to environmental conditions. However, conventional brick production often has negative environmental impacts, including carbon emissions and the use of non-renewable natural resources. On the other hand, agricultural waste such as sugarcane husks is a problem in itself, as it is abundantly available but often not optimally utilized. The use of sugarcane husks as an additional material in the synthesis of brick ceramics is one solution that can reduce waste while improving the properties of brick materials (Pramono & Winarno, 2025). From an ethnoscience point of view, the use of sugarcane husks also reflects local wisdom that uses natural resources wisely, in accordance with the principles of sustainability.

Previous research has shown the significant potential of sugarcane husks to improve the mechanical and thermal properties of building materials. A study found that adding rice husk ash to the concrete mixture can increase compressive strength and resistance to high temperatures (Suranto et al., 2023) . In addition, other research shows that using sugarcane husks as an additive in brick production can reduce material density without sacrificing strength, resulting in lighter, more economical products (Marjuki, M., Wahyuni, D., & Asri, 2025). Further research found that adding sugarcane husks to brick production improves brick microscopic characteristics by increasing silica content and makes bricks safer than cement-based bricks. These findings form a strong scientific basis for the development of these teaching materials (Pramono & Winarno, 2025).

In ethnoscience courses, this teaching material adopts an interdisciplinary approach, integrating materials science, local wisdom, and economic perspectives. This integration enables students to understand how modern technology can be harmonized with existing cultural values and traditions. Meanwhile, in the technopreneur course, the material provides a step-by-step guide for developing innovative products derived from sugarcane husks into viable business opportunities. Through this process, students are encouraged to learn key competencies such as market analysis, production cost calculation, marketing strategies, and business sustainability planning.

However, several persistent problems in existing higher education teaching materials remain evident. These include their fragmented and disciplinary nature, with limited meaningful integration across science, technology, culture, and economic perspectives. Additionally, the lack of contextualization with local potential reduces their relevance to students' real-life environments and constrains their contribution to local economic empowerment. There is also an insufficient connection between theoretical understanding and practical entrepreneurial skills, particularly in transforming local resources into value-added products. Furthermore, teaching materials tend to be dominated by cognitive-oriented content, often neglecting the development of innovation, creativity, and technopreneurial competencies. Recent studies highlight the urgency of a more integrative approach, showing that the use of local materials can enhance product competitiveness while supporting local economies (Muliani, F., & Munandar, 2022), and emphasizing the importance of technopreneurship-based education in preparing students for workforce challenges (Suban, A., & Gani, 2024).

In addition to contributing to the field of education, this teaching material has broader implications for national development. It supports the creation of innovative products, such as sugarcane husk-based brick ceramics, which align with government efforts to reduce carbon emissions and enhance resource efficiency (Efarras F.N & Putri, 2024). In the long term, this innovation contributes to achieving the Sustainable Development Goals (SDGs), particularly Goals 9 (Industry, Innovation, and Infrastructure) and 12 (Responsible Consumption and Production). These contributions highlight the strategic role of integrative, context-based learning materials in fostering environmentally responsible innovation and strengthening the local economy.

However, despite these significant potentials, a clear research gap remains. There is still limited availability of integrative studies that simultaneously connect ethnoscience approaches,

material science innovation, and technopreneurship within a single coherent teaching material. Most previous studies tend to focus separately on the utilization of local materials, instructional model development, or entrepreneurial aspects, without systematically linking them into a comprehensive learning framework (Sihombing et al., 2025; Wang et al., 2025). Furthermore, there is a lack of empirically grounded teaching resources that guide students from conceptual understanding to product development and commercialization, grounded in local wisdom, as well as minimal alignment between curriculum content and real-world sustainability challenges. Therefore, this research not only aligns with the vision of UIN Syekh Wasil Kediri, the Faculty of Tarbiyah, and the science study program in integrating science with the Indonesian local context, but also addresses this gap by offering a holistic, integrative, and application-oriented reference reflected in ethnoscience and technopreneur courses within the science study Program.

METHODOLOGY

Research and Development Model

This research is a development research A Teaching Material for Environmentally Friendly Brick Ceramic Innovation: Synthesis and Economic Value of Adding Sugarcane Husks. The development model of the science education laboratory management model product that will be used by the researcher is *"Four-D Models"* which consists of 4 stages, namely (Thiagarajan, 1974): 1. *Define,* 2. *Design,* 3. *Develop* and 4. *Disseminate*. Design of the development of teaching materials for environmentally friendly Brick Ceramic Innovation: Synthesis and Economic Value of Sugarcane Husk Addition can be systematically described as in Figure 1.

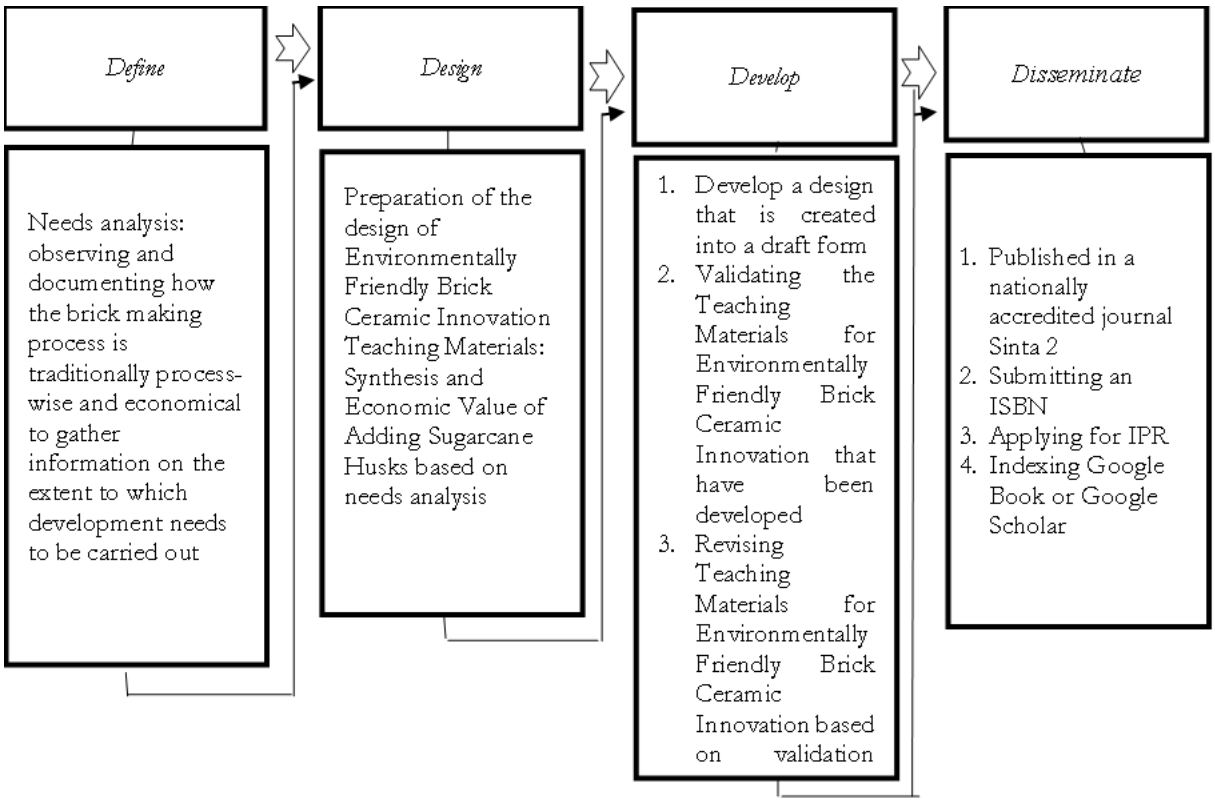

Figure 1. Design of the Development of Teaching Materials for Environmentally Friendly Brick Ceramic Innovation: Synthesis and Economic Value of Sugarcane Husk Addition

Trial Subject

The test subjects at the development stage of *Environmentally Friendly Brick Ceramic Innovation Teaching Materials: Synthesis and Economic Value of Adding Sugarcane Husk* consist of material physicist validators, economist validators, and learning expert validators, involving a total of four expert validators and 100 students from the Tadris IPA program at IAIN Kediri; the selection of these subjects is based on clear academic considerations, namely that material physicist validators are needed to ensure the scientific validity and feasibility of the material synthesis concepts, particularly in relation to the physical and mechanical properties of brick ceramics, economist validators are involved to assess the accuracy and relevance of the economic value analysis including production cost calculations, market feasibility, and business potential, while learning expert validators are selected to evaluate the pedagogical aspects such as content organization, instructional design, readability, and alignment with learning outcomes, and the involvement of 100 students is intended to represent the actual target users of the teaching materials so that data on practicality, readability, attractiveness, and effectiveness can be obtained empirically in a real learning context, thereby ensuring that the developed teaching materials are not only theoretically valid but also applicable, user-friendly, and capable of improving students' understanding and skills.

Data Type

The data to be analyzed was obtained from the validation of material physicist validators, physical material expert validators and economic validators. The following is the description of the data that will be used: (a) Quantitative data, this data was obtained from the results of verification from validators, validators, material physicists, and economic validators; (b) Qualitative data, qualitative data is obtained based on comments, criticisms, suggestions and inputs from validators related to product development outcomes.

Data Analysis Techniques

The data collected from this study were analyzed and then used to change the teaching materials of Environmentally Friendly Brick Ceramic Innovation: Synthesis and Economic Value of Adding Sugarcane Husks, which were developed so that the teaching materials of Environmentally Friendly Brick Ceramic Innovation: Synthesis and Economic Value of Adding Sugarcane Husks are feasible and meet the criteria that have been set. To produce averages and percentages, descriptive statistical data analysis was used. Some of the data analysis techniques used include: (a) Qualitative data analysis is found from the result data in the form of input and; (b) also suggestions given by material physicist validators and economist validators when validating which will affect the product revision process carried out by the development of it; (c) Quantitative data analysis obtained from quantitative data the results of each validator will be calculated using the formula as below:

$$\text{percentage} = \frac{Total\ Score\ from\ Validator}{Maximum\ Score} \times 100\% \quad (1)$$

The calculation of the validator results is used for each question presented in the form of a questionnaire. To find out the criteria for product validity, it can be stated in the table 1 (Creswell, 2023) .

Table. 1 Product Validity Criteria

No	Category	Valuation
1.	Very valid	85%-100%
2.	Valid	75%-85%
3.	Quite valid	50%-75%
4.	Invalid	25%-50%

Quantitative data analysis was also obtained from the student response questionnaire sheet which is data about student responses to the developed learning tools to see the practicality of the developed product. The data from the results of student responses were analyzed in a quantitative descriptive manner by describing the percentage in each question. The questionnaire that has been filled out is calculated based on the following formula (Creswell, 2023).

$$\%\text{Criteria} = \frac{Total\ Score}{Criteria\ Score}\ x\ 100\ \% \quad (2)$$

After the analysis is carried out on the results of the student response questionnaire, the results will be analyzed and the practicality of this teaching module will be concluded with the perception criteria listed in table 2 (Klare, 1963).

Table 2. Criteria for Perception of Student Responses

Score	Perception criteria
0% - 20%	Very bad
21% - 40%	Bad
41% - 60%	Enough
61% - 80%	Good
81% - 100%	Excellent

RESULT AND DISCUSSION

Validity of Teaching Materials

A panel of four experts thoroughly reviewed and validated the teaching materials to ensure their effectiveness and suitability for classroom use. This evaluation focused on assessing the feasibility of the teaching modules prior to their implementation in learning activities. The panel comprised two experts in educational theory and practice and two professionals from the development industry, each bringing valuable insights to the process. This study aims to provide feedback and input on the teaching materials developed by researchers, ensuring those that meet the good category and are subsequently valid for use in learning. Teaching materials can be used in the process of data collection in institutions, because the results of the analysis by experts can be said to be valid.

Table 3. Teaching Material Validity Assessment Data

No	Aspects Assessed	Validator Assessment				Average	Remarks	Percentage of Agreement
		V1	V2	V3	V4			
1	Format	3,7	3,5	3,5	3,7	3,6	Highly Valid	90%
2	Isi	3,5	3,3	3,5	3,5	3,45	Valid	86,25%
3	Language	3,5	3,5	3,7	3,7	3,6	Highly Valid	90%

Table 3. shows the average validity by the four validators for the format aspect of 3.6 with *a Percentage of Agreement* of 90%, the content aspect of 3.45 with *a Percentage of Agreement* of 86.25%, the language aspect of 3.6 with a *Percentage of Agreement* of 90%. The results of this validation show that the teaching materials developed are valid so that they can be used at the implementation/research stage.

Practicality of Teaching Materials

Learning tools that have undergone expert validation and yielded study results with scores or assessments in the good category can be considered valid and used for research. The practicality of the learning tool is reviewed based on student responses, and the research's obstacles are identified. The results of the analysis are presented as a description of the average score and the percentage for each aspect of data collection. The implementation of learning in this study also collects data on students' readability of the teaching materials that have been developed. Students are asked to provide a readability response to this teaching material by filling out student response sheets. Data on student responses to learning are contained in Table 4.2 (Klare, 1963).

Table 4. Student Response Results to Readability of Teaching Materials

No.	Aspects Assessed	Average Percentage	Remarks
1	Ease of understanding sentences in teaching materials	87%	Excellent
2	Use of terms that are appropriate to the student's ability level	92%	Excellent
3	Absence of confusing or ambiguous sentences	86%	Excellent
4	Logical and easy-to-follow material delivery flow	92%	Excellent
5	Paragraphs are neatly arranged and not too long	95%	Excellent
6	Headings/subheadings help understand the content of the material	93%	Excellent
7	The content of the material is easy to understand without any additional help	85%	Excellent
8	Examples or illustrations help explain the concept	91%	Excellent
9	Explanation is not too complicated	90%	Excellent
10	Font size is easy to read	95%	Excellent
11	Font type is clear and doesn't strain the eye	95%	Excellent
12	Proportional spacing and margins	95%	Excellent
13	Images/diagrams support the understanding of the mater	95%	Excellent
14	Illustrations are not confusing or too dense	90%	Excellent
15	Good visual quality (contrast, brightness, and sharpness)	90%	Excellent
16	Text length is not too long or boring	86%	Excellent
17	The division of material into subsections makes it easy to read	87%	Excellent
18	The material does not seem long-winded	90%	Excellent
19	Interesting teaching materials to read	93%	Excellent
20	Delivery of material motivates to continue learning	90%	Excellent
21	The use of contextual examples makes learning relevant	93%	Excellent
22	Each part is related and supports each other	91%	Excellent
23	Transitions between topics go smoothly	89%	Excellent
24	No parts are disconnected or difficult to connect to the previous contents	89%	Excellent
25	Good and correct grammar	90%	Excellent
26	Consistent and rule-appropriate spelling	90%	Excellent
27	No writing errors that interfere with comprehension	93%	Excellent
28	The difficulty level of the text according to the student's level	91%	Excellent
29	The level of conceptual abstraction is in line with their abilities	87%	Excellent
30	No term is too technical without explanation	93%	Excellent
Average percentage of student responses		**90.8%**	**Excellent**

Based on Table 4, the best student response to the Paragraph aspect is neatly organized and not too long. The font size is comfortable to read, the font type is clear and does not strain the eyes, the line spacing and proportional margins are comfortable, and images/diagrams support the understanding of the material by 95%. It is important to note that while all materials are classified as proficient, some achieve an 85% score in the Content section, indicating that they are easily comprehensible without the need for additional assistance. Overall student response to the

readability of the teaching materials: 90.8%. It indicates that students' reactions to the teaching materials created are favorable in terms of readability.

The Validity of Teaching Materials for Environmentally Friendly Ceramic Innovations

The validation results of four validators, comprising two learning experts and two building industry experts, showed that the teaching materials developed received the category of Valid to Very Valid across three main aspects: format, content, and language. These findings show that the teaching materials have met the initial feasibility standards required in the 4-D model development study, confirming that the expert validation stage is a critical component for ensuring theoretical suitability, content accuracy, and usability prior to field implementation. The expert validation is a formative form of evaluation that aims to improve the product before it is disseminated, so that strong validation results are the basis for the teaching material being on the right track (Gay, L. R., Mills, G. E., & Airasian, 2012).

The average value for the format aspect was 3.6, with *a Percentage of Agreement* of 90%, indicating that the design of the teaching materials was in accordance with the principles of effective instructional design. Format aspects include layout, structure consistency, information presentation, and delivery flow. It aligns with the theory that teaching materials should be designed to make it easier for users to process information systematically (Dick, W., Carey, L., & Carey, 2015). The Book confirms that good visual display, paragraph consistency, and material organization improve readability and speed up comprehension, which seems to be reflected in the results of validation of excellent formatting aspects (Prastowo, 2012).

The content aspect received an average score of 3.45 (86.25%), which falls within the Valid category, though slightly lower than the other aspects. It shows that the material is relevant, accurate, and in accordance with the learning objectives. However, there may still be room for improvement in the depth of explanation or the accuracy of certain concepts. In research on the development of teaching materials, the content must meet the principles *of content accuracy, relevance,* and *curricular alignment*, as conveyed in the revised Bloom Taxonomy (Anderson, L. W., & Krathwohl, 2021). Research on the integration of ethnoscience into teaching materials also emphasizes the importance of the relationship between scientific content and its applicable context, so that the material becomes easier to understand and more meaningful for students (Lovy Herayanti, Fuaddunnazmi, 2025). The results of this content validation indicate that the teaching material is already in the good category, but it is still open to adjustment in depth.

The language aspect received a score of 3.6 (90%), indicating that the language style, sentence structure, and use of terms were consistent with the student's ability level. The use of good language is part of the principle *of readability*, which explains that concise, clear, and unambiguous sentences increase readers' understanding and comfort in learning the material (Klare, 1963). Science research literacy-based teaching materials also show that communicative, non-technical language significantly influences student understanding, especially in abstract or scientific materials. Excellent language validation results show that teaching materials have met these principles (Wisdayana, N., Achyani, A., Aththibby, A. R., & Pratiwi, 2025).

The high agreement across all three aspects (86.25%–90%) indicates consistency among validators in their assessments. It means the experts' judgments are reliable and not influenced by individual biases. A high agreement value indicates that validation instruments are of good quality and are used consistently by experts (Creswell, 2023). Thus, the validation results not only reflect the quality of the teaching materials but also illustrate that the validation procedure has been carried out appropriately and objectively. Overall, the validation results indicate that the developed teaching materials are suitable for classroom use during the trial stage. The high validity values in the format and language aspects, as well as in the content aspect, indicate that the teaching material has met the minimum quality standards in development research. From the perspective of

formative evaluation theory, products with strong validation results can proceed to the implementation stage because they have undergone a refinement process informed by expert input. Thus, this teaching material has passed a critical phase in product quality and is ready to be assessed in terms of practicality and effectiveness in application in the field.

The Importance Teaching Materials for Environmentally Friendly Ceramic Materials

Students scored 95% on the paragraph structure aspect, which shows that the arrangement of ideas in each paragraph is very effective in reducing the cognitive load of students so that they can fluently understand the content of the teaching material without often returning to the previous paragraph, which is one of the indicators of the readability quality of academic texts. It is in line with the principle *of readability* that paragraphs that focus on one main idea and are arranged coherently facilitate the processing of information in the reader's short- and long-term memory (Klare, 1963). Previous research also shows that a good paragraph structure significantly improves students' understanding of science texts in scientific learning modules (Nurhayati, 2023). Thus, the empirical findings showing a high score on paragraph structure are supported by evidence that good textual grammar is a major factor in the practicality of teaching materials in higher education, especially for technical materials such as eco-friendly brick innovations.

High student responses (90–93%) on language and term aspects indicate that the use of vocabulary, technical terms, and sentence structure in teaching materials is appropriate to students' level of understanding, thereby reducing the possibility of misinterpretation or confusion when reading complex material. It is supported by the *Plain Language* theory put forward by Redish (2000), which states that simplifying language without reducing its scientific essence can help readers absorb information faster, as well as research that proves that the use of clear and consistent terms in science modules can statistically improve students' readability scores (Hanifah et al., 2025). Therefore, a high score on the language aspect not only reflects the quality of the teaching materials empirically but is also consistent with the literature evidence that the right language is an important prerequisite for the development of practical and accessible teaching materials.

A score of 95% on visual elements indicates that students highly value illustrations, diagrams, neat layouts, comfortable-to-read font sizes, and proportional margins and spacing, so that the reading experience is not only informative but also visually comfortable, reinforcing understanding of the concepts described in the text. These findings are consistent with *the Cognitive Theory of Multimedia Learning* which states that simultaneous presentation of text and visuals optimizes information processing through dual channels (Mayer, 1997), as well as the findings that visual quality in science teaching materials contributes significantly to improving conceptual understanding (Asilestari, P., Henjilito, R., & Hardi, 2025). Therefore, the high score on the visual design aspect supports the argument that a good graphic appearance and layout are important contributors to the practicality of teaching materials, which are ready for further testing in the classroom context.

Students rated the flow of material delivery and the transitions between chapters as excellent (more than 90%), indicating that the material is arranged in a logical order from basic concepts to practical applications so that readers can build a knowledge framework gradually without confusion, which is important in technical and multi-dimensional materials such as sugarcane-based building material innovations. This stance is supported by the instructional design theories of which emphasize that the structure of the material must be sequential and sequential to facilitate the internalization of effective learning (Dick, W., Carey, L., & Carey, 2015; Gagne, 1985), as well as research on contextual e-books that show a positive relationship between a good flow of material and students' increased understanding of concepts that are relatively new to them (Laksono, R. Z., & Hardiyanto, 2025). Thus, the empirical findings on the logical flow aspect not only demonstrate the high quality of the teaching material but are also consistent with the scientific evidence that supports the importance of systematic material structure.

A score of 90–93% on the relevance and motivation indicators shows that students feel that the material in the teaching materials is not only easy to read, but also relevant to real experiences and local contexts such as the utilization of sugarcane husk waste as well as technopreneurship opportunities, which triggers an intrinsic interest in digging further. This is supported by *Contextual Teaching and Learning Theory* which states that material is easier to understand and internalize when the context is directly related to the student's real world (Holubnycha, L., Kostikova, I., Besarab, T., & Koshechkina, 2025; Jhonson, 2014), as well as by research which reports that contextual-based e-books significantly increase motivation and learning engagement compared to abstract modules (Rahayu, D. P., & Lieung, 2025). Therefore, the contextual relevance of your teaching materials not only empirically increases student engagement but is also supported by empirical evidence that the relationship between academic concepts and real context is able to consistently increase motivation to learn.

The overall score of 90.8% indicates that the developed teaching materials are highly practical for use in actual learning contexts. This high level of practicality is reflected in several aspects, including readability, clarity of concepts, cognitive and affective engagement, and students' ability to relate the material to real-life situations. The score exceeds the commonly accepted minimum standard of practicality in instructional development research (≥80%), which is typically used as a benchmark for feasibility in field trials or broader implementation. This finding is also consistent with previous studies showing a strong relationship between practicality and the effectiveness of teaching materials, particularly in project-based learning and case-study approaches in science and technology education. From both instructional design theory and empirical perspectives, high-readability materials tend to facilitate more meaningful learning experiences, thereby supporting the conclusion that this product is ready for implementation and further effectiveness testing. Importantly, the novelty of this research lies in the integrative design of teaching materials that combine ethnoscience, material science innovation, and technopreneurship within a single coherent framework.

However, several limitations should be considered when interpreting these findings. First, the research subjects were limited to students of the Tadris IPA Program at UIN Syekh Wasil Kediri, thereby limiting the generalizability of the results to broader higher education contexts. Second, the study primarily focused on development and practicality aspects, without comprehensively examining effectiveness in improving learning outcomes, higher-order thinking skills, and technopreneurship competencies through more rigorous experimental designs. Third, the number of expert validators was limited to four, potentially reducing the diversity of academic and pedagogical perspectives in the validation process. Additionally, the innovation scope was confined to the use of sugarcane husk waste for eco-friendly brick production and has not yet expanded to a broader range of locally sourced resource-based innovations. Finally, the study did not include longitudinal analysis to assess the sustainability of learning outcomes or the long-term impact of the teaching materials on students' entrepreneurial behavior

CONCLUSION

This study successfully created teaching materials for Environmentally Friendly Brick Ceramic Innovation utilizing sugarcane husk waste through the 4D model, demonstrating both validity and practicality for educational use. Validation by four experts yielded scores of 3.6 (90%) for format, 3.45 (86.25%) for content, and 3.6 (90%) for language, all categorized as valid to highly valid. Furthermore, a practicality assessment with 100 students showed overwhelmingly positive feedback, achieving an overall average of 90.8%, with several key metrics reaching 95%, such as paragraph structure, font size and type, and visual quality. Other metrics fell within the range of 85% to 93%, signifying high levels of readability, clarity of language, and understanding of

concepts. Consequently, these teaching materials are not only academically sound but also effectively support learning that is contextual, innovative, and focused on technopreneurship.

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