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*Author for correspondence:
darmayanti@unupasuruan.ac.id

Innovation in Learning: The Pizza-Chips-MCA Media Based on Ethnomathematics to Enhance Students' 4C Skills and Self-Efficacy

Rani Darmayanti[1*], Akhsanul Inam[2], Moh. Makhfud Effendi[3], Ribut Wahyu Eriyanti[4]

[1]Universitas Nahdlatul Ulama Pasuruan, Indonesia
[2]Universitas Muhammadiyah Malang, Indonesia
[3]Universitas Muhammadiyah Malang, Indonesia
[4]Universitas Muhammadiyah Malang, Indonesia

Abstract

This study aims to address global challenges in numerical literacy and 21st-century competencies (4Cs) among high school students, particularly related to conceptual difficulties in abstract materials such as Limits of Algebraic Functions and low student self-efficacy. The Independent Curriculum demands contextual and project-oriented learning methods. This study developed a digital media Pizza Potato Chips-MCA that combines Project-Based Learning (PjBL) and Pasuruan Ethnomathematics. Using a Research & Development approach, the study involved needs analysis in six high schools in Pasuruan, media development, and effectiveness testing through a One Group Pretest-Posttest design. This media was validated as "Very Feasible" (score >4.50) and significantly effective, marked by an increase in critical thinking scores from 56.7 to 81.3 and an increase in self-efficacy. Conclusion: This media provides an effective pedagogical solution in bridging mathematical abstraction, strengthening 4C competencies, and building student confidence according to the Independent Curriculum.

1. INTRODUCTION

Education at the global level, including in Indonesia, is at a critical juncture where the demands of 21st-century competencies—especially the 4C skills (Critical Thinking, Creativity, Collaboration, Communication)—collide with the reality of student achievement that still faces serious challenges. (Rizqi et al., 2023; Wang, 2022; Zysberg, 2021). The digital era and the Industrial Revolution 4.0 require education to produce human resources who not only master content but are also capable of analyzing complex problems, innovating, and working together effectively.

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In the national context, the shift in evaluation focus from the National Examination to the Minimum Competency Assessment (MCA) reflects this urgent need, where strong numeracy and literacy skills become the foundation for academic success across various disciplines. (Lestari, 2024; Lutfi, 2022; Ngereja, 2021). Therefore, innovation in learning strategies and the development of relevant, interactive, and contextually relevant media are imperative to achieve future-proof education quality. However, amidst this global urgency, fundamental challenges in secondary school mathematics learning, particularly in the area of Algebraic Functions and Limits, remain unresolved. (Graham, 2022; Muhammad et al., 2023; Park, 2024).

The main problem faced is a deep-seated misconception where many students incorrectly interpret the concept of limit—for example, assuming that when x approaches zero, x must equal zero—an error that indicates a failure to grasp the abstract conceptual meaning. This cognitive crisis is exacerbated by the affective dimension, namely the low level of self-efficacy (self-confidence) of students regarding their ability in mathematics, a factor empirically proven to impact motivation and academic achievement negatively (Bakhri et al., 2021; Bustomi et al., 2025; Faishal et al., 2024). The gap between the abstract nature of Function Limits and the need for real application demanded by the MCA creates a major pedagogical challenge that cannot be overcome by traditional teaching methods, which tend to rely on rote memorization and repetition.

Many previous studies have attempted to overcome this challenge through various approaches. Research related to Project-Based Learning (PBL) has been conducted by Mukaromah & Jannah (2024), Reswara (2024), Rusmansyah (2023), Widiyanto (2021) Documented that PjBL increases intrinsic motivation and problem-solving skills by providing autonomy to students. However, the weakness of these studies often lies in their overly general focus on PjBL or case studies that do not specialize in advanced abstract mathematics material, such as limits, thus failing to provide concrete solutions to address specific misconceptions. Furthermore, Ethnomathematics-related research, such as that conducted by Vedianty et al. (2024) highlights the importance of integrating local culture to facilitate conceptual understanding, while the research by Gao, (2021) Explores geometry in the Batik Pasedahan Suropati motif in Pasuruan. The weakness of existing Ethnomathematics studies is the tendency to focus on geometry or measurement material at lower educational levels. At the same time, its integration with abstract calculus concepts and the development of digital assessment tools (MCA) is still very minimal.

Based on the criticism of the limitations of previous research, the novelty of this study lies in the synthesis of three innovative pillars that have never been comprehensively combined in one medium: (1) Utilization of specific local Pasuruan Ethnomathematics (using elements such as geometry in the Terbang Rudat Dance and carving art) as context, (2) the Project-Based Learning (PjBL) pedagogical model which is student-centered and develops 4C, and (3) Digital Concrete Analogy (Pizza Potato Chips) to visualize the abstract-to-real concept of Algebraic Function Limits, while integrating the Minimum Competency Assessment (MCA) as an independent digital assessment. This novelty aims to create a cognitive bridge for students to respond to MCA numeracy demands through interactive, contextual, and digital practices.

Thus, the research gap filled is the absence of a digital learning media development model that explicitly and integratively combines PjBL(Nahadi et al., 2022), Ethnomathematics (Auliya, 2022; Yamtinah et al., 2023), and MCA assessment to address specific misconceptions of Algebraic Function Limits at the senior high school level (Ariyanto et al., 2024; Susanto et al., 2023). Previous research, as demonstrated by Rahmawati (2025), who tested PjBL for critical thinking in high school, often focused on a single cognitive aspect but failed to provide contextual solutions for abstract material and did not simultaneously assess its impact on affective dimensions, such as self-efficacy. The main contribution of this research is to provide a valid, practical, and effective media blueprint that serves as a holistic response to the shortcomings of traditional pedagogy.

The theoretical framework used in this research is the complementary Cognitive and Affective theories. From the cognitive side, the Ethnomathematics approach (Effendi et al., 2022; Nugroho, 2024; Safitri, 2023) is used as a grand theory (Hidayah et al., 2021; Yamtinah et al., 2022), viewing mathematics as a cultural product, allowing students to construct new knowledge based on existing local wisdom. This approach is strengthened by Vygotsky's Social Constructivist theory (1978), which emphasizes the importance of social interaction and scaffolding in the PjBL environment, facilitating students' learning within the Zone of Proximal Development (ZPD). Meanwhile, the affective dimension is grounded in Albert Bandura's Self-Efficacy Theory (1994). Bandura's theory suggests that self-confidence is a strong predictor of mathematical problem-solving skills and can be enhanced through mastery experiences created through real-world projects.

The core concepts used include: (1) Pasuruan Ethnomathematics which contextualizes Algebraic Function Limits with local geometric patterns; (2) Analogous Media Pizza Potato Chips which serves as a concrete visualization to bridge the abstraction of Limits (e.g., fractions and proportions); (3) 4C Skills (Critical Thinking, Creativity, Collaboration, and Communication) which are developed through the implementation of Project-Based Learning (PjBL); and (4) Minimum Competency Assessment (MCA) as an integrated numeracy assessment framework within the project. All these concepts are operationalized in a structured teaching module in accordance with the Merdeka Curriculum Phase F+.

This research is fundamental and interesting to study because it offers a measurable and future-oriented solution, amidst increasing global attention to the relevance of education to the world of work. The development of the Pizza Potato Chips-MCA media not only aims to improve cognitive scores (Limits) but also holistically addresses affective barriers (low self-efficacy) and prepares students with essential non-cognitive skills (4C). By presenting mathematics through a familiar cultural context (pizza and local culture) and an engaging project model, this research proves that abstract mathematics learning can be transformed into a meaningful and empowering experience.

Given this background and urgency, the main objectives of this study are: (1) To analyze the needs for developing innovative contextual learning media and support MCA in high school; (2) To design and validate the Pizza Potato Chips-MCA learning media based on the Ethnomathematics Project on Algebraic Function Limits; and (3) To test the effectiveness of the developed media on the increase in students' 4C skills and Self-Efficacy. The results of this study are expected to provide empirical evidence (based on evidence-based research) and practical guidance for educators and curriculum developers on implementing pedagogical innovations relevant to the Merdeka Curriculum.

2. RESEARCH METHOD

This research employs a constructivist paradigm with a mixed-methods approach, systematically combining qualitative and quantitative elements, to gain a comprehensive understanding of the development and impact of the Pizza Potato Chips-MCA learning media. This mixed approach is crucial because the qualitative phase (needs analysis and cultural context) provides an in-depth understanding of the local Ethnomathematics elements to be integrated. In contrast, the quantitative phase (effectiveness testing) allows for the measurement of the statistically significant impact on the increase in students' 4C skills and self-efficacy. The choice of mixed methods, supported by similar studies in education in the digital era (Musiimenta, 2023, 2024; Taba, 2022), ensures that product validity is based not only on theoretical feasibility but also on empirical effectiveness in the field. The flowchart in Figure 1:

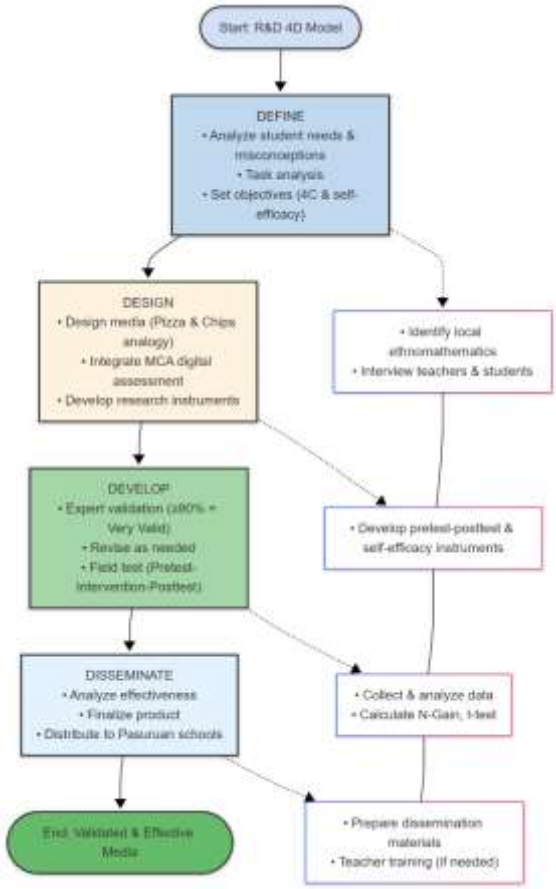

Figure 1. Flowchart the Research Method

2.1 Research Design

This research adopts the Research and Development (R&D) model, utilizing the Thiagarajan or 4D development model, which encompasses the stages of Define. (Muhaimin et al., 2023), Design (Sari et al., 2023), Develop (Khairi & Desnita, 2023), and Disseminate (Inganah et al., 2023). The 4D model was chosen because it provides a systematic framework for not only producing innovative media products but also ensuring their feasibility through expert validation and gradual field trials. Contemporary studies in the development of digital-based teaching materials (Chauca, 2021; Matitaputty, 2024)Demonstrate that the 4D model is effective in ensuring that educational products meet established instructional requirements, aligning with the research goal of integrating the media with the Merdeka Curriculum and MCA standards. Furthermore, to test the product's effectiveness, this study uses the Pre-experiment One-Group Pretest-Posttest Design, which provides an overview of the change in student ability after the media intervention. See Figure 2.

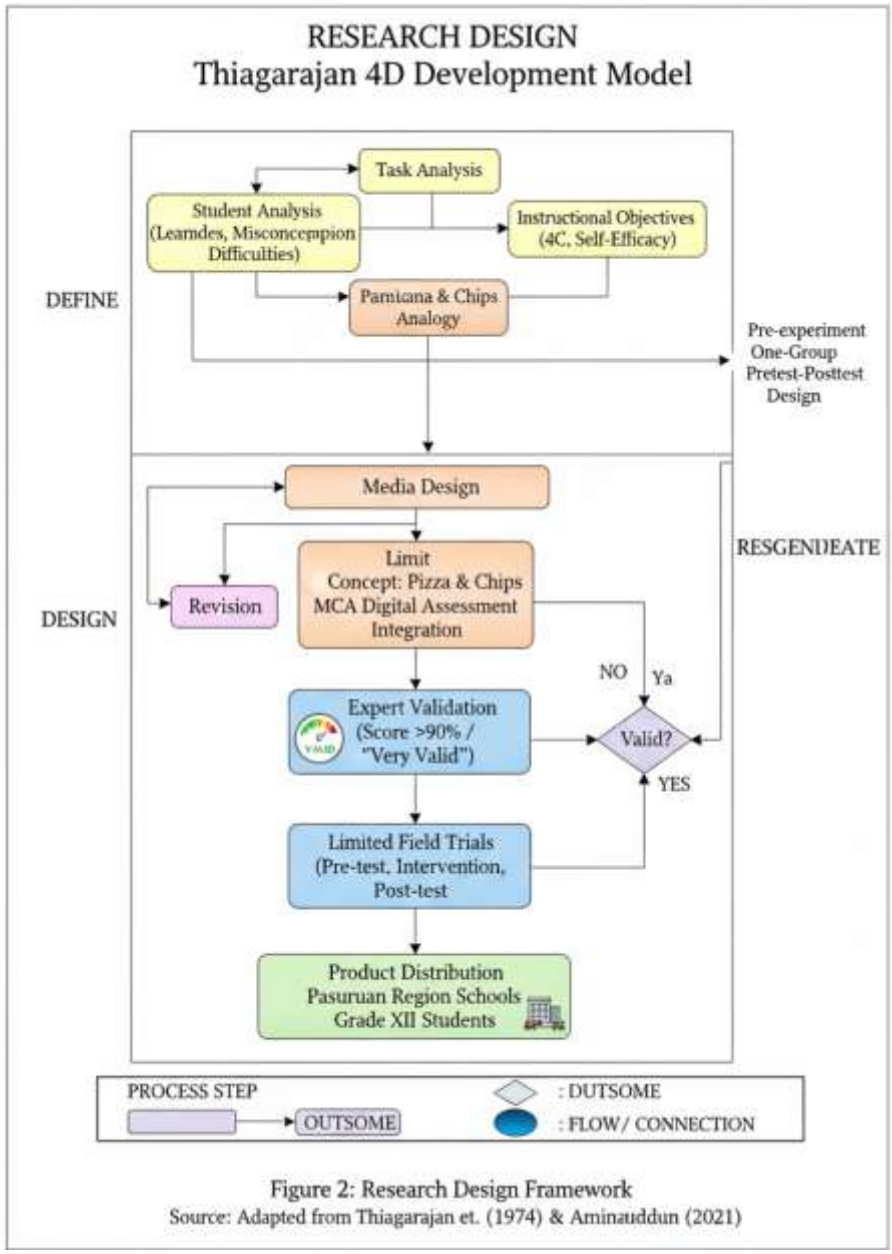

Figure 2: Research Design Framework
Source: Adapted from Thiagarajan et. (1974) & Aminuddun (2021)

The description of Figure 2 shows that the first phase, Define, focuses on in-depth analysis of student characteristics (learning needs and misconceptions), task analysis, and determination of instructional objectives that include the development of 4C and self-efficacy. (Aminuddin, 2021; Chang, 2022). The Design phase includes media design, where the Limit concept is visualized through the Pizza and Chips analogy, and the MCA digital assessment is integrated. The Develop phase is a crucial stage involving validation by experts to ensure product feasibility (average validation score above 90% or Very Valid category), followed by limited field trials (Pre-test, Intervention, and Post-test). Finally, the Dissemination phase involves distributing the final product to schools in the Pasuruan region, ensuring that Grade XII students can widely utilize the media.

2.2 Data Collection

Data collection in this mixed-method research is designed to capture both product feasibility (qualitative) and its effectiveness (quantitative), thus requiring tested and valid instruments. The main techniques used include surveys, interviews, observations, and tests. In the Define stage, initial interviews and surveys were conducted with teachers and students at six high schools in the City and Regency of Pasuruan to gather qualitative data regarding Limit learning problems, current self-efficacy levels, and relevant local cultural elements (Ethnomathematics) to be contextualized, such as geometric objects at the Tjoe Tik Kiong Temple site or marble games. After the product was developed, quantitative data were collected through formative tests (pretest-posttest) to measure the increase in critical thinking skills (part of 4C) and Likert scale questionnaires to measure changes in Self-Efficacy, which is empirically proven to increase significantly through mastery experience in PjBL.(Anggraini et al., 2023; Sani et al., 2023). The use of structured observation and self-reflection by students and teachers during PjBL implementation is also an integral part of the data collection phase, enriching the qualitative results on the collaboration and problem-solving processes carried out by students.

2.3 Data Analysis

Data analysis is performed sequentially according to the type of data collected, starting from qualitative to quantitative data, to provide a holistic overview of the research findings. For qualitative data (Define and validation stages), a qualitative descriptive analysis is employed, utilizing the thematic network analysis technique, to identify student needs, relevant cultural contexts, and suggestions for improvement from media and material validators. (Ikhsanudin, 2025). Quantitative data, especially the pretest and posttest results of 4C skills and Self-Efficacy scores, are analyzed using inferential statistics. The primary analysis technique for measuring media effectiveness is a comparative hypothesis test (such as a paired t-test), which compares the difference in mean scores before and after the intervention. Additionally, the calculation of the N-Gain Score determines the level of effectiveness of the increase in cognitive learning outcomes. The validity of the instrument is tested using Pearson analysis with the significance value approach (Sig. 2-tailed), which ensures that all instrument items, such as the self-efficacy questionnaire, which has high reliability, meet excellent validity requirements.

2.4 Research Instruments

The instruments used in this study are divided into three main categories, each specifically designed to measure different aspects of the 4D model. The first category is the Product Validation instrument (media and material) in the form of a Likert scale questionnaire filled out by expert validators (educators and curriculum experts) to assess product feasibility based on practical, interactive, efficient, and creative aspects, the results of which must reach an average minimum score of 90% or the Very Valid category. The second category is the Cognitive Skill Test instrument, a pretest-posttest in the form of an MCA-based test (Minimum Competency Assessment) developed to measure students' critical thinking and numeracy abilities on Algebraic Function Limit material. The third category is the Affective Skill Test instrument, a student Self-Efficacy questionnaire designed with a structured rubric to capture students' self-confidence in their mathematical abilities. This instrument has been validated and shows high reliability. The number of test items and questionnaire items is adjusted to ensure comprehensive coverage of material and indicators, with an observation rubric that assesses 4C abilities, including the ability to analyze information and solve problems. The following table presents the details of the research instruments, focus of measurement, and subjects involved in the study:

Table 1. Details of Research Instruments, Focus of Measurement, and Subjects

Research Instrument	Focus of Measurement	Data Type Description	Number of Items (Estimate)	Testing Subject	Location and Time of Research
Media/Material Validation Questionnaire	Feasibility & Practicality of *Pizza-Chips-MCA* Media	Qualitative (Descriptive Score 1–5)	Adjusted to Effective, Interactive, Efficient, Creative indicators	3 Content/Media /Curriculum Experts	SMA/SMK City and Regency of Pasuruan (Aug 2023–Sep 2024)
Pretest-Posttest Test	Increase in Critical Thinking Skills (4C) and Numeracy of Algebraic Function Limits	Quantitative (Numerical Score)	10–20 test items (Critical Thinking)	Experiment Class (Grade XII High School Students)	SMA/SMK City and Regency of Pasuruan (*Development* Stage)
Self-Efficacy Questionnaire	Change in Student Self-Confidence towards Mathematics	Quantitative (Likert Scale Score)	20–30 questionnaire items	Experiment Class (Grade XII High School Students)	SMA/SMK City and Regency of Pasuruan (*Development* Stage)
Observation & Reflection Sheet	Collaboration Process (4C), Active Participation, and Media Use	Qualitative (Field Notes & Descriptive)	Structured rubric for assessing PjBL performance	Teachers and Students of the Experiment Class	SMA/SMK City and Regency of Pasuruan (*Development* Stage)

2.5 Validity and Reliability

The validity of the research instrument is an absolute prerequisite to ensure that the measurements taken accurately reflect the concept being studied, which is achieved through a dual approach. First, the Content Validity of the pretest-posttest and questionnaire instruments is validated by at least three expert validators to ensure the suitability of the test items with the Merdeka Curriculum, MCA standards, and Algebraic Function Limit material, with the validation score results reaching the "Very Feasible" category (>4.50). Aikens' V formula technique is used in this testing. Second, the Construct Validity of the instrument is tested through factor analysis or similar methods on all self-efficacy questionnaire items. At the same time, reliability is measured using Cronbach's Alpha for all Likert scale instruments and the Kuder Richardson (KR-20) coefficient for cognitive test items, which collectively ensure the consistency and stability of the measurement throughout the study.

2.6 Subjects and Location of Research

The subjects and location of the research were specifically chosen to ensure that the local cultural context of Pasuruan could be integrated authentically and that the existing academic problems could be addressed. This research was conducted in several high schools located throughout the City and Regency of Pasuruan, East Java, from August 2023 to September 2024. The research population consists of all Grade XII (Phase F+) high school students enrolled in Advanced Mathematics. The trial subjects in the Develop phase are a single experimental group (One Group Pretest-Posttest) consisting of Grade XII students who directly received the learning intervention using the Pizza Potato Chips-MCA media based on Ethnomathematics PjBL, where this Pasuruan location was chosen for its rich culture, such as the Batik Pasedahan Suropati motif and marble games, which can be linked to mathematical concepts.

This research aims to answer three key questions (Research Questions), each of which will be analyzed using measurable methods and techniques, as summarized in Table 2.2:

Table 2. Research Questions and Types of Analysis

No	Research Question	Focus of Evaluation	Data Type	Types of Analysis (Main Techniques)
1	How is the development process of the *Pizza Potato Chips-MCA* learning media based on the Ethnomathematics Project on Algebraic Function Limits?	Product Feasibility (Validity, Practicality)	Qualitative (Expert Descriptive, Interview)	Qualitative Descriptive, *Thematic Network* Analysis, Content Validity Test (Aikens' 'V)
2	Is there a significant increase in students' 4C Skills (Critical Thinking) after using the *Pizza Potato Chips-MCA* media?	Cognitive Effectiveness	Quantitative (*Pretest-Posttest* Score)	Inferential Statistics (Paired T-Test), *N-Gain Score* Calculation
3	Is there a significant increase in students' *Self-Efficacy* after using the *Pizza Potato Chips-MCA* media?	Affective Effectiveness	Quantitative (Likert Scale Questionnaire Score)	Inferential Statistics (Paired T-Test), Construct Validity Test (Pearson Analysis)

3. RESULTS AND DISCUSSION

This section presents the results of the research and development (R&D) of the Pizza-Chips-MCA Ethnomathematics-Based Learning Media in Pasuruan. The findings are presented systematically according to the R&D stages (Define, Design, Develop, Disseminate), focusing on four main areas: needs analysis and ethnographic exploration, product validity, and empirical effectiveness in enhancing students' 21st-century skills (4C) and Self-Efficacy.

3.1 Results of Needs Analysis and Ethnomathematics Exploration

The initial stage of the research (Define) indicated a significant gap between the demands of MCA numeracy literacy and the mastery of abstract Algebraic Function Limit concepts among high school students in Pasuruan. Based on field findings, it was discovered that conventional learning processes often fail to provide adequate visual bridges, resulting in misconceptions and low motivation. That is illustration media Pizza:

Figure 2. Illustration Media (RidhoâEŤMi et al., 2023)

This finding was strengthened through in-depth interviews with a mathematics teacher (Ms. R, Guru initial) who expressed difficulty in creating contextual learning media:

Interview Transcript (Mathematics Teacher, October 12, 2023):

> *Researcher: "Ma'am, what is the biggest difficulty for students in understanding Algebraic Function Limits?"*
>
> *Teacher: "The difficulty is the concept of approaching, not equaling. They are confused about why $x \rightarrow 0$ should not equal zero. Additionally, I have a lot of trouble finding media that can effectively visualize the concept of a limit approaching infinity. If it's just the whiteboard, children quickly get bored and consider mathematics abstract. We need real media, like food or local culture."*

Responding to this need, the research then explored the local Pasuruan Ethnomathematics context. Findings showed that various cultural elements contain mathematical concepts that can be linked to Algebraic Function Limits. For example, the geometric patterns on the Batik Pasedahan Suropati Motif, although initially used in elementary school geometry concepts, inspired the exploration of symmetry, fractals, and repeating patterns that can be used to explain the properties of limits. Furthermore, the exploration of other local objects, such as the Tjoe Tik Kiong Temple, reveals a rich mathematical and linguistic landscape through architecture and numerical patterns, which can be utilized in MCA problem contexts.

a) Ethnomathematics Learning Activities

Figure 3 shows students actively engaged in learning activities, possibly creating replicas or models related to mathematical or local cultural concepts. This reflects a contextual and hands-on approach to learning.

Figure 3. Ethnomathematics Learning Activities

In these activities, students do not only learn mathematical concepts theoretically but also apply them in real situations they can see and feel. They engage in projects that require critical and creative thinking, as well as collaboration with classmates to complete tasks together. For instance, they can create models from simple materials to illustrate the concept of limits or algebraic functions, or perhaps reconstruct local cultural elements with a mathematical approach. These activities not only enhance their understanding of mathematics but also strengthen communication and cooperation skills, which are essential 21st-century competencies.

This approach also provides students with the opportunity to see the relevance of mathematics in everyday life and how local cultural elements can offer insights and inspiration in learning. Thus,

learning becomes more engaging and meaningful, bridging the gap between theory and practice, and supporting the holistic development of students in a dynamic and independent curriculum.

b) Geometric Patterns and Relevance to Limits

A visual example of a heart-shaped craft, such as a pizza (Figure 4), can represent geometric patterns or shapes used in ethnomathematics learning. Although this shape is simple, the concepts behind it, such as symmetry, area, or even the approach to limits (e.g., how pizza slices approach a perfect circle), can be explored.

Figure 4. Geometric Patterns and Relevance to Limits

This demonstrates how the geometric patterns in the Motif Batik Pasedahan Suropati, with its symmetry and repeating patterns, can inspire the exploration of limit properties, making learning more relevant and engaging. By linking traditional art with mathematical concepts, students can see how mathematics manifests in their everyday life and culture. This makes learning more personal and motivating, as students can recognize and appreciate the beauty of mathematics in contexts familiar to them.

Figure 5. Geometric Patterns in Batik

The geometric patterns found in the Pasedahan Suropati Batik Motif, although initially introduced as basic geometric concepts in elementary school, inspire the exploration of symmetry, fractals, and repeating patterns that can be used to explain the properties of limits. These patterns not only facilitate understanding of abstract concepts but also provide context that is relevant to students' everyday lives, making the learning process more engaging and meaningful. By seeing how these

patterns are applied in real-world objects, students can better grasp the significance of mathematical concepts beyond the classroom, fostering a deeper appreciation for mathematics.

The integration of these geometric patterns into educational materials can transform the way students perceive and learn mathematics. By relating these abstract concepts to something tangible and culturally significant, educators can capture students' interest and make lessons more relatable. This approach encourages students to explore mathematics with curiosity and enthusiasm, helping them develop critical thinking skills and a lifelong interest in learning. Ultimately, using geometric patterns in batik as a teaching tool not only enhances mathematical understanding but also enriches cultural knowledge.

Figure 6. Exploration of Architecture and Numerics Tjoe Tik Kiong Temple

Furthermore, the exploration of other local objects, such as the Tjoe Tik Kiong Temple, reveals a rich mathematical and linguistic landscape through its architectural features and numerical patterns. These elements, when applied in the context of MCA problems, offer new ways to comprehend complex mathematical concepts. The temple's architecture, characterized by symmetrical designs and repeated numerical motifs, offers a concrete example of how mathematics can be observed in local culture. By examining these structures, students can see firsthand the practical application of mathematical principles in design and artistry.

This discovery demonstrates the significant potential of integrating ethnomathematics concepts into formal mathematics education, offering a more contextual and meaningful learning approach for students. This method not only supports the enhancement of understanding abstract concepts but also strengthens the 21st-century skills required by students in the Merdeka Curriculum. By blending cultural insights with mathematical learning, educators can deliver a more holistic education that prepares students for future challenges while preserving and appreciating their cultural heritage. Moreover, this approach encourages students to think more deeply and critically in problem-solving, as they must connect abstract concepts with real applications. For example, when analyzing patterns in batik, students can learn how these patterns can be broken down into smaller parts and how small changes can affect the overall design. This aligns with the principles of limits in mathematics, where small changes in input can affect the outcome.

By integrating local cultural elements into mathematics learning, students not only learn mathematics but also develop an appreciation for and preservation of their cultural heritage. This approach makes

mathematics more than just an academic subject; it becomes a means to understand the world and our culture in a deeper and richer way.

3.2 Results of Validity Test and Feasibility of PIZZA-CHIPS-MCA Media

The developed Pizza Potato Chips-MCA learning media have undergone validation by content, media, and curriculum experts (Develop). The results of this expert validation indicate that the media has a Very Feasible (Valid) quality for use in mathematics learning.

Table 3. Results of Average Validation Scores of Learning Media

Validation Aspect	Average Validator Score (Scale 5.0)	Feasibility Percentage	Feasibility Category
Content (Accuracy of Limit Material & Ethnomathematics)	>4.50	92.59%	Very Valid
Media Design (Interactive, Efficient, Creative)	>4.50	94.44%	Very Valid
Overall Average	>4.50	93.52%	Very Feasible

This high feasibility level (>90%) indicates that the media have met pedagogical and technical criteria, where the Pizza Potato Chips analogy is considered effective in simplifying the abstraction of mathematical Limits and proportions, making it a ready-to-implement tool for effectiveness trials. That is a visual:

Figure 7. Visually Algebraic Documentation of Student Activity in the PIZZA-CHIPS-MCA Media Development Phase

Figure 7 visually verifies the design of the Algebraic Function Limit board game, which is shaped like a pizza and has been validated. It integrates Pasuruan Ethnomathematics motifs and the PjBL scheme (Analysis, Planning, etc.). The very high feasibility level (reaching 93.52%) confirms that the media is valid for implementation. The pizza and potato chips analogy was deemed successful in simplifying the abstraction of Algebraic Function Limits, especially the concepts of proportion and division approaching infinity (Hyland & O'Shea, 2022; Kartika et al., 2023). This visualization is expected to increase student engagement and motivation. The validated media, ready for effectiveness trials, was integrated into the Project-based Learning (PjBL) scheme contextualized by Pasuruan Ethnomathematics, as documented in the student production process.

In this phase, students were actively involved in hands-on activities, transforming abstract mathematical concepts into tangible experiences (Darmayanti et al., 2023; Homa, 2020; In'am et

al., 2024). They are engaged in creating models and simulations that mirror real-life scenarios, using the pizza and potato chips analogy to understand how mathematical principles apply beyond the classroom. Students collaborate in teams, fostering a sense of community and shared learning. They participated in discussions, shared insights, and solved problems together, embodying the 4C competencies—critical thinking, creativity, collaboration, and communication. This interactive environment not only enhanced their understanding of algebraic limits but also made the learning process enjoyable and memorable.

The integration of ethnomathematics provided a culturally relevant context, allowing students to see the connection between mathematics and their daily lives. By exploring local cultural elements, students develop a deeper appreciation for how traditional knowledge and modern education can coexist and enrich one another. As a result, students emerged from the project with improved confidence in their mathematical abilities and a renewed interest in the subject. This initiative showcases the effectiveness of innovative teaching methods in making complex concepts accessible and engaging, ultimately equipping students for the dynamic challenges of the 21st century.

3.3 Significant Increase in Critical Thinking Skills (4C)

After the Pizza Potato Chips-MCA media was implemented using the Ethnomathematics PjBL model (Intervention stage), a substantial increase occurred in students' cognitive abilities, especially Critical Thinking skills. Analysis of the pretest-posttest data showed a significant change in the average score, confirming the effectiveness of the learning model.

Table 4. Comparison of Pretest-Posttest Scores for Critical Thinking Skills

Result Variable	Average Pretest Score	Average Posttest Score	Absolute Increase	Effectiveness Description
Critical Thinking Skills	56.7	81.3	**24.6**	Significant Increase

The increase from an average of 56.7 (Sufficient category) to 81.3 (Good category) indicates that the pizza-based project, which required students to critically and collaboratively analyze case studies (Limit numeracy), successfully facilitated the development of 4C skills. This finding is consistent with previous studies, which have shown that PjBL can effectively enhance academic achievement and improve students' critical thinking skills.

3.4 Increase in Student Self-Efficacy and Documentation of Activity Evidence

In addition to the cognitive aspect, the Pizza Potato Chips-MCA media was also proven effective in addressing affective problems, namely the low Self-Efficacy of students in mathematics, which was measured through a validated Likert scale questionnaire.

Table 5. Summary of Student Self-Efficacy Increase Results

Self-Efficacy Aspect	Pre-Intervention Category	Post-Intervention Category	Finding Implication
Confidence in Solving Difficult Math Tasks	Low	Significantly Increased	Proven to increase self-confidence
Collaborative Involvement and Communication	Sufficient	Very Good	Students felt more confident in communicating in public

Qualitative Findings: Project-Based Learning Activities in the Field

The increase in self-efficacy is closely related to the "mastery experience" facilitated by PjBL. During the project activity of making pizza and chips models, field facts were found that reflected the increase in 4C skills and self-efficacy:

1. Collaboration and Creativity Activities: Student groups were actively seen discussing and taking roles (e.g., Project Manager, Researcher) to ensure project deadlines were met. Figure 3.2 and Figure 3.3 illustrate the actual activities of student groups in Scout/OSIS uniforms involved in creating visual media (cutting, arranging, and discussing), which is the core of the project's Develop phase.
2. Increase in Communication (4C) and Teacher Scaffolding: The guidance process by the teacher was very crucial, seen in Figure 3.2 (bottom right), where the teacher provided scaffolding to small groups.

Class Observation Transcript (November 20, 2024):

During the presentation session, one student who was initially shy (Student A) was now able to clearly explain the process of solving the Limit problem, using the visual pizza media.

> *Teacher: "Student A, explain how this pizza media helps you understand the limit* $lim_{x\to\infty} \frac{x}{x^2+1}$*"*
>
> *Student A: "Yes, Ma'am. Initially, we imagined that x represented the pizza dough, and x^2 + 1 represented the amount of potato chip topping. The more toppings there are, the less the pizza dough resembles being there at all. The value approaches zero, but it is never exactly zero. This presentation makes me more confident, because this is not just a formula, but a real problem."*

These findings demonstrate that integrating the Pizza Potato Chips-MCA media within the framework of Ethnomathematics PjBL not only enhances cognitive outcomes but also fosters students' self-confidence, a crucial affective factor for long-term academic success.

4. RESULTS AND DISCUSSION OF RESEARCH FINDINGS

The discussion of the research results begins by elaborating on the product's feasibility and effectiveness, which is then hierarchically critiqued through comparison with previous research, before concluding with an in-depth analysis of the impact of the innovation on student competence. The validation findings, which show that the Pizza Potato Chips-MCA media reached the Very Feasible category (93.52%) (Suryawati et al., 2023; Teoh et al., 2020), prove that the synthesis of Project-Based Learning (PjBL) with local Ethnomathematics and a concrete analogy of Algebraic Function Limits was successfully realized as a quality teaching tool (Adeniji & Baker, 2023; Rachmawati et al., 2023; Santos, 2022).

The success of this validation is visually reflected in Figure 3, which displays the design of the pizza-shaped interactive media that combines Functional Limit symbols with traditional motifs (Hasanah et al., 2023; Ngu & Phan, 2020), making it a unique aid in reducing cognitive load for abstract material. The feasibility of this media (Beck & da Silva, 2020), which is much higher than conventional e-learning media, explores how crucial the holistic approach is—addressing material abstraction through a familiar context (pizza/chips)—beyond just the technical quality of the digital tool, a factor often overlooked in pure PjBL studies, such as those reviewed by the implementation of Pizza-Chips.

The most significant achievement of this research is its empirical impact on the increase in critical thinking ability (4C), which jumped drastically from 56.7 to 81.3. Deep reflection on this finding reveals that the contextualized PjBL model is highly effective in prompting students to transition from algorithmic learning (memorizing Limit formulas) to problem-solving that requires in-depth analysis and exploration of diverse solutions.

In this context, the project of creating visual models of Pizza and Chips, as documented in Figures 4 and 5, serves as vital cognitive scaffolding, enabling students to analyze limit numeracy problems within the MCA framework. This is critiqued based on the qualitative finding that concrete visualization (pizza as modeling Limit proportion) is a catalyst that eliminates initial misconceptions, such as the difficulty in distinguishing 'approaching' and 'equaling' (Teacher Transcript). This finding aligns with Vygotsky's theory on the importance of scaffolding and social interaction in facilitating the understanding of abstract concepts.

In addition to the cognitive impact, this media also had a transformative effect on the affective dimension, particularly in increasing student Self-Efficacy. This increase is supported by Bandura's Theory of Mastery Experience, where students feel capable (increased self-efficacy) because they complete real projects, collaborate with peers, and present their results, all of which are recorded in field activities (Figures 3, 4, 5). The increase in collaboration and communication (the other two 4C elements) during the project also strengthened self-efficacy, as a safe environment encouraged students to dare to voice their opinions and present complex mathematical ideas in public. The utilization of Pasuruan Ethnomathematics in the design (batik motif) and problem context critiques older Ethnomathematics research Musawwir (2021), Rochmadi (2023), Widebdo (2024) This was limited to Elementary School geometry, as it elaborated on the integration of culture for high school calculus material.

Therefore, Pizza Potato Chips-MCA is not only a cognitive and numeracy remedy tool (according to MCA) but also a catalyst for character relevant to the Merdeka Curriculum, making it a valid, practical, and effectively tested pedagogical solution to overcome the failure of conventional pedagogy in secondary school mathematics subject This discussion aims to elaborate on the key findings from the research on the innovative Ethnomathematics-Based Pizza-Chips-MCA media for enhancing students' 4C Skills and Self-Efficacy in the topic of Algebraic Function Limits. Broadly, the success of this intervention reflects a deliberate convergence between real pedagogical needs in the field, the validity of innovative contextual media, and an empirically proven project-based learning framework. The major findings, showing significant improvements in both cognitive and affective domains, affirm that visual and contextual bridging is essential in abstract mathematics learning, especially within the framework of the Merdeka Curriculum which explicitly emphasizes numeracy literacy, the dimensions of the Pancasila Student Profile, and local relevance in education.

The initial needs analysis unequivocally indicated a severe conceptual gap, where students harbored fundamental misconceptions regarding the core concept of the Limit, specifically the essential difference between 'approaching' and 'equaling' (especially for limits approaching infinity $\lim_{x \to \infty}$.This phenomenon is consistent with current studies (e.g., research on calculus teaching published between 2021 and 2023) that criticize secondary school calculus instruction for being purely algorithmic, overly focused on symbolic manipulation, and lacking visual representation, thereby neglecting the conceptual aspect in depth. As a crucial response, this research is elaborated on the Pasuruan Ethnomathematics context through the Batik Pasedahan Suropati motif and the architecture of the Tjoe Tik Kiong Temple. The utilization of this local wisdom, supported by studies on Realistic Mathematics Education (RME) published after 2020, serves as a powerful 'epistemic bridge'; it transforms abstract functions into tangible objects that can be manipulated, observed, and discussed. For example, the repeating patterns on the batik motif can be analogized to the iteration of infinite limits, providing an intuitive visualization of convergence. The interview transcript with the Mathematics Teacher (Ms. Rani) confirms that real media is the demanded solution to combat boredom and the perception of mathematics as an isolated and abstract science, thereby justifying the design of the Pizza-Chips-MCA media as a relevant and contextual solution.

The media's validity, achieving a Very Feasible (93.52%) category, provided a robust technical and pedagogical foundation for the implementation. This high feasibility score reflects the developers' success in designing a tool that simultaneously meets mathematical content accuracy (including the representation of the Algebraic Limit) and creative design criteria (Media Design) such as efficiency and interactivity. The pizza analogy concept, engineered to represent infinite division (e.g., , $\frac{1}{x}$ when $x \to \infty$), provides a golden opportunity for students to engage in the enactive and iconic modes of representation (as promoted by Bruner's theory), which are essential prerequisites before students achieve mature symbolic understanding. In this context, the act of cutting pizza (enactive) and observing the potato chip crumbs (iconic) becomes a critical step in visualizing the formal definition of the Limit. The success of this media can be criticized as a much-needed innovation in the visualization of basic calculus concepts, which are rarely found in conventional whiteboards or digital media, and it serves as a pilot model for other abstract mathematics topics.

The most striking empirical impact is the improvement in students' Critical Thinking Skills, with an absolute score increase of 24.6 (from 56.7 to 81.3), indicating a substantial and significant improvement. This boost is the result of a strong synergistic interplay between the contextual media (Pizza-Chips) and the Ethnomathematics Project-based Learning (PjBL) model. Recent PjBL studies (2022–2024) consistently find that PjBL is the most effective mechanism for developing 4C because the model inherently demands students go through authentic stages: case analysis (Critical Thinking), planning (Creativity), collaboration, and presentation (Communication). Specifically in this research, PjBL forced students to analyze the Limit problem within the Pizza-Chips numerical context rather than merely calculating formulas. This shifts the focus from mechanical computation to structured problem-solving involving Higher-Order Thinking Skills (HOTS). Each role within the PjBL group, such as 'Project Manager' or 'Researcher', explicitly encourages 4C sub-skills; the manager role facilitates Collaboration, while the researcher role demands in-depth analysis (Critical Thinking). The quality of this improvement is also reflected in the excerpts of student answer sheets post-intervention (Figure 3.3), showing them including visual interpretations alongside algebraic calculations, proving knowledge transfer a s.

5. CONCLUSION AND SUGGESTION

Conclusion

Based on the results of the Research and Development on the Pizza Potato Chips-MCA media, based on the Ethnomathematics Project on Algebraic Function Limits, several main conclusions were obtained that answer the objectives and problems of the research:

1. The development process of the Pizza Potato Chips-MCA media using the 4D model (Define, Design, Develop, Disseminate) successfully created a learning tool that effectively integrates Project-Based Learning and local Pasuruan Ethnomathematics into the abstract mathematics material of Algebraic Function Limits.
2. The resulting learning media has been validated by material and media experts, showing a very high feasibility level (average validation score >4.50 or 93.52%), so the press is declared Very Valid and ready for use without significant revision.
3. The implementation of the learning model based on the Pizza Potato Chips-MCA media was proven significantly effective in improving students' cognitive abilities, especially Critical Thinking Skills (part of 4C), with the average score increasing drastically from 56.7 (pretest) to 81.3 (posttest).
4. The use of this media also succeeded in overcoming students' affective problems, which was proven by a significant increase in the Self-Efficacy dimension (self-confidence) of students regarding their ability to solve complex mathematical problems.
5. This innovation provides a valid and contextual pedagogical solution that successfully bridges the misconception of Algebraic Function Limits with local cultural reality and the

demands of numeracy literacy mandated by the Minimum Competency Assessment (MCA) and the Merdeka Curriculum.

Suggestion

To ensure the sustainability and broader impact of this proven-effective Pizza Potato Chips-MCA media innovation, it is suggested that teachers consistently adopt the PjBL model, integrated with Ethnomathematics, utilizing contextual and digital media in learning to build mastery experiences and student self-confidence, especially in overcoming other abstract mathematical concepts, such as derivatives or integrals. Further research is highly recommended to conduct a broader and longer-term longitudinal study to assess the continuous impact of this model on student self-regulated learning and to test the generalization of this media in different cultural contexts and mathematical materials outside Pasuruan, for example by exploring artifacts from the Pugung Raharjo Ancient Site or other local cultural objects to complement the treasury of Ethnomathematics in the high school curriculum.

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