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THE EFFECT OF PROJECT-BASED LEARNING (PJBL) USING PIZZALUV–MATHEMATICS MEDIA ON SELF-EFFICACY AND 4C SKILLS

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In the era of modern education, effective instruments to measure 4Cs and students' self-efficacy are urgently needed. This study aims to (1) compare the mathematics skills of students taught using the PjBL model with Pizzaluv-Mathematics media and students taught using the PBL model; (2) measure the effect of PjBL on students' self-efficacy; and (3) evaluate the impact of PjBL on 4Cs. This study was conducted on twelfth-grade students at MAN 2 Malang, Indonesia, in the context of algebraic function limits. Pizzaluv-Mathematics media is designed to help students complete learning projects through communication, collaboration, and critical and creative thinking in making a "Love" shaped math pizza using visual media. This study used a quasi-experimental design involving 72 students divided into an experimental group (PjBL) and a control group (PBL) based on pre-existing class divisions. Data were collected using tests and questionnaires to measure self-efficacy and 4C abilities. Self-efficacy was assessed using a standard scale with proven validity and reliability, while 4C skills were measured through performance tasks and peer evaluations with strict objectivity standards. Two-way analysis of Variance (ANOVA) showed a significant difference in mathematics learning ability that favored the PjBL model using Pizzaluv-Mathematics media ($p < 0.05$, $\eta^2 = 0.11$). The results of one-way ANOVA also showed significant differences in 4C ability and self-efficacy between student groups ($p < 0.01$). In addition, Pearson correlation analysis revealed a strong positive relationship between 4C ability and self-efficacy ($p < 0.01$). The findings of this study indicate that the PjBL model using Pizzaluv-Mathematics media positively impacts students' self-efficacy and 4C ability.

Keywords: 4C skills, "PIZZA" paper media, mathematics, self-efficacy, innovative learning, PjBL.

Abstrak

Di era pendidikan modern, instrumen yang efektif untuk mengukur 4C dan efikasi diri siswa sangat dibutuhkan. Penelitian ini bertujuan untuk (1) membandingkan keterampilan matematika siswa yang diajarkan menggunakan model PjBL dengan media Pizzaluv-Mathematics dan siswa yang diajarkan menggunakan model PBL; (2) mengukur pengaruh PjBL terhadap efikasi diri siswa; dan (3) mengevaluasi dampak PjBL terhadap 4C. Penelitian ini dilakukan pada siswa kelas dua belas di MAN 2 Malang, Indonesia, dalam konteks limit fungsi aljabar. Media Pizzaluv-Mathematics dirancang untuk membantu siswa menyelesaikan proyek pembelajaran melalui komunikasi, kolaborasi, dan berpikir kritis dan kreatif dalam membuat pizza matematika berbentuk "Love" menggunakan media visual. Penelitian ini menggunakan desain quasi-eksperimental yang melibatkan 72 siswa yang dibagi menjadi kelompok eksperimen (PjBL) dan kelompok kontrol (PBL) berdasarkan pembagian kelas yang sudah ada sebelumnya. Data dikumpulkan menggunakan tes dan kuesioner untuk mengukur efikasi diri dan kemampuan 4C. Efikasi diri dinilai menggunakan skala standar dengan validitas dan reliabilitas yang terbukti, sementara keterampilan 4C diukur melalui tugas kinerja dan evaluasi rekan sejawat dengan standar objektivitas yang ketat. Analisis Varians Dua Arah (ANOVA) menunjukkan perbedaan yang signifikan dalam kemampuan belajar matematika yang mendukung model PjBL menggunakan media Pizzaluv-Matematika ($p= 0.004$, $\eta^2 = 0,11$). Hasil ANOVA satu arah juga menunjukkan perbedaan yang signifikan dalam kemampuan 4C dan efikasi diri antara kelompok siswa ($p= 0.001$). Selain itu, analisis

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korelasi Pearson mengungkapkan hubungan positif yang kuat antara kemampuan 4C dan efikasi diri (p= 0,01). Temuan penelitian ini menunjukkan bahwa model PjBL menggunakan media Pizzaluv-Matematika berdampak positif terhadap efikasi diri dan kemampuan 4C siswa.

***Kata kunci**: Keterampilan 4C, media kertas "PIZZA", matematika, efikasi diri, pembelajaran inovatif, PjBL*

INTRODUCTION

In today's rapidly evolving educational landscape, fostering students' self-efficacy and 4C skills—creativity, communication, collaboration, and critical thinking—has become increasingly critical. These competencies are essential for students to thrive in a complex, interconnected world. With technological advancements and globalization, the ability to think critically, innovate, collaborate effectively, and communicate proficiently has never been more valuable. Thus, education must evolve to equip students with the necessary tools and opportunities to develop these skills.

Developing the 4C skills (4Cs) is integral to preparing students for future challenges (Darmayanti et al., 2022; Jannah et al., 2023; Sekaryanti et al., 2022). These skills are crucial not only for academic achievement but also for success in various professional (Busha et al., 2021; Darmayanti, 2024; Nesterova et al., 2024) and personal contexts (An et al., 2024; Raza et al., 2023). One effective approach to foster these skills is Project-Based Learning (Chikurteva, 2023; Lim et al., 2023; Zahroh, Darmayanti, et al., 2023), which emphasizes both mastery of academic content (Lo, 2020; Siverling et al., 2019; Vidyastuti et al., 2022) and the development of essential skills like critical thinking (Cholily et al., 2023), collaboration (Zahroh, Rachmawati, et al., 2023), and problem-solving (Cahyadi et al., 2023). Through PjBL, students engage in relevant and meaningful projects that require the application of knowledge in real-life scenarios. This approach not only deepens their understanding of the subject matter but also enhances their self-efficacy as they witness tangible results from their efforts.

Self-efficacy, defined as the belief in one's capability to succeed, is a key determinant of academic performance and motivation (Naifeld & Nissim, 2022; Rizki et al., 2022). Students with high self-efficacy are more likely to approach challenges positively (Darmayanti, Utomo, et al., 2023; Safitri et al., 2023), persist in finding solutions (González et al., 2020), and view obstacles as opportunities for mastery (Li et al., 2024). They tend to set higher goals (Varriale et al., 2024), exert more effort (Mubarok et al., 2023), and demonstrate greater resilience when faced with adversity (Gredes et al., 2022). In educational settings, PjBL can play a critical role in building self-efficacy by providing students with the academic knowledge and life skills necessary for future success.

Pizzaluv-Mathematics emerges as a novel educational tool designed to enhance students' mathematics learning experiences (Darmayanti et al., 2024). It utilizes interactive elements to teach complex algebraic concepts through the creative design of "Love" shaped pizzas, making abstract mathematics more engaging and increasing students'

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motivation and understanding (Ridho'i et al., 2023). Previous research has Alkandari & Alabdulhadi, (2023, and Darmayanti, In'am, et al., (2023) demonstrated the positive impact of PjBL on students' self-efficacy, highlighting the importance of innovative educational strategies in boosting academic success and personal growth.

PjBL is an instructional approach that emphasizes student-centered learning through engaging and meaningful projects. Recent studies have indicated that PjBL effectively integrates the acquisition of knowledge and skills by challenging students to solve real-world problems (In'am, Effendi, Darmayanti, Usmiyatun, & Choirudin, 2024), thereby promoting deeper learning (Liu et al., 2024), critical thinking (Yang et al., 2018), and the application of knowledge in practical contexts (Remacle et al., 2023; Vidergor, 2023). This pedagogy has been particularly successful in mathematics education, where it enhances students' problem-solving abilities and engagement, providing a dynamic shift from traditional teaching methods (Akcaoglu & Akcaoglu, 2022). By fostering an environment where students can apply what they learn to tangible projects, PjBL supports the development of essential skills needed in the 21st century (Khun-Inkeeree et al., 2020).

The 4C skills—creativity (Supena et al., 2021), communication (Asgafi et al., 2023), collaboration (Sugianto et al., 2022), and critical thinking (Rosyid et al., 2023a)—are essential competencies for the 21st century (Vidyastuti et al., 2018). Creativity involves generating novel and valuable ideas (Susetyarini et al., 2024), while communication effectively conveys information and ideas (Rizki et al., 2023). Collaboration is working effectively with others towards a common goal (Johnson & Johnson, 1989), and critical thinking involves analyzing and evaluating information to make reasoned decisions (Ennis, 1993). Integrating these skills into educational practices prepares students for future challenges and opportunities (Trilling & Fadel, 2009).

Despite the recognized benefits of PjBL, prior studies often suffer from limitations such as inadequate experimental designs and a narrow focus on academic achievement, neglecting the crucial aspects of self-efficacy and 4C skills. Furthermore, the lack of longitudinal data has restricted understanding of the long-term impacts of educational interventions. This study seeks to address these gaps by specifically examining the impact of PjBL using Pizzaluv-Mathematics media on self-efficacy and 4C skills, providing empirical evidence to support the integration of innovative educational media in enhancing cognitive and affective learning outcomes learning outcomes.

The study is conducted among twelfth-grade students at MAN 2 Malang, Indonesia, leveraging the school's modern facilities and experienced educators. MAN 2 Malang was chosen for this study due to its suitability for testing PjBL with Pizzaluv-Mathematics media. The research focuses on evaluating academic achievement, self-efficacy, and 4C skills, engaging students in creative projects like designing a "Love" shaped pizza using mathematical concepts. Utilizing a quasi-experimental design with control and experimental groups ensures a comprehensive assessment.

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Pizzaluv-Mathematics media, as a new educational tool used in this research, integrates visual and interactive elements to make abstract mathematical concepts more real and exciting. This method encourages students to work collaboratively on creative projects, enhancing their 4C skills. This research aims to (1) compare the mathematical abilities of students taught using the PjBL model with Pizzaluv-Mathematics media with those taught using the PBL model; (2) measure the influence of PjBL on student self-efficacy; and (3) evaluate the impact of PjBL on students' 4C skills.

METHODS

To address previous reviewer comments and enhance the study's rigor, the research method has been revised to better align with the study's objectives and context. This section outlines the specific procedures and methodologies employed in the study, focusing on the impact of PjBL using Pizzaluv-Mathematics media on self-efficacy and 4C skills among twelfth-grade students at MAN 2 Malang, Indonesia.

1. Research Design and Sample

a. Research

This study used a quasi-experimental design with pre-test and post-test control groups. This design allows for the evaluation of the impact of the intervention while controlling for extraneous variables that may affect the results. The study was conducted over a three-month period during the 2023/2024 academic year, focusing on the limits of algebraic functions.

To provide a clear picture of the research process, Figure 1 illustrates the methodological flow, detailing each step from sample selection to data analysis.

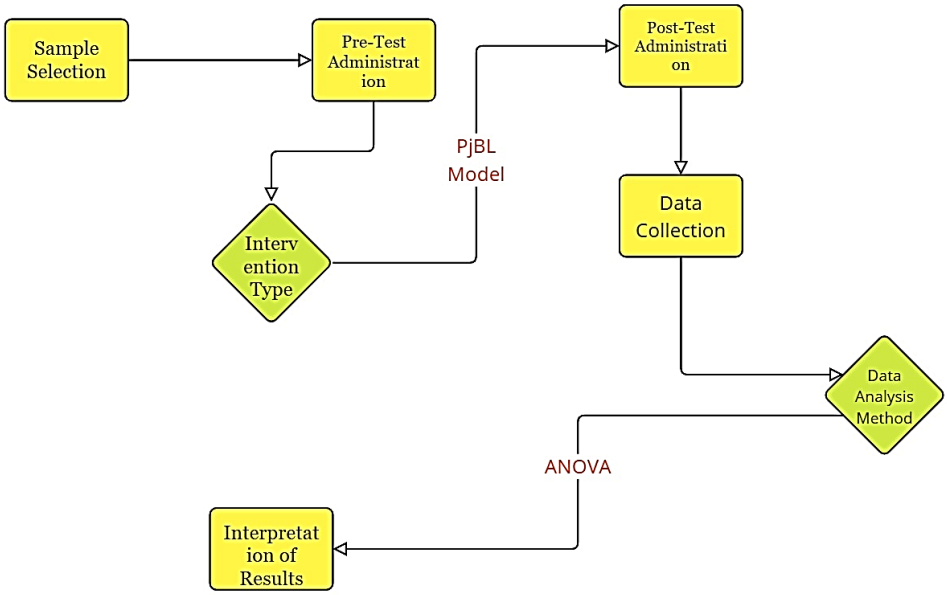

Figure 1. Research Methodology flowchart (elaboration author's)

Figure 1 provides a comprehensive overview of the research process, depicting the methodological flow from sample selection to data analysis. The steps outlined include sample selection, conducting a pre-test, implementing an

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intervention model such as PjBL or PBL, conducting a post-test, collecting data through questionnaires and assessments, analyzing the data using methods such as ANOVA, regression, and path analysis, followed by interpretation of the results. This flowchart effectively summarizes the structured approach taken throughout the study.

b. Sample Selection

This The study involved 72 twelfth-grade students from MAN 2 Malang, selected through stratified random sampling based on their academic performance in mathematics and willingness to participate. The students were divided into two groups: an experimental group (PjBL with Pizzaluv-Mathematics media) and a control group (PBL). The sample distribution ensures a balanced representation of gender and academic achievement, as detailed in Table 1.

Table 1. Demographic Characteristics of the Sample

Group	Total Students	Gender (Male/Female)	Average Math Score
Experimental	36	18/18	75.5
Control	36	17/19	74.8

2. Data Collection Technique

a. Instruments

To evaluate the impact of PjBL using Pizzaluv-Mathematics media, several instruments were employed, ensuring comprehensive assessment across key areas:

1) Mathematics Achievement Test

A standardized test designed to assess students' understanding of algebraic function limits was administered to both experimental and control groups, ensuring a comprehensive evaluation of their mathematical skills. This test has been validated by a panel of mathematics educators and boasts a reliability coefficient of 0.89, indicating a high level of accuracy in measuring students' mathematical abilities (Smith et al., 2021).

2) Self-Efficacy Scale

The modified version of Bandura's (2006) self-efficacy scale comprises 10 items rated on a 5-point Likert scale, effectively assessing students' confidence in their abilities. This scale has shown remarkable reliability, achieving a coefficient of 0.91, which highlights its consistency in measuring self-efficacy among students, as noted by Johnson & Marzano (2020).

3) 4C Skills Assessment

The assessment comprised performance tasks and peer evaluations, where students tackled real-world problems and received feedback based on a rubric that outlined specific criteria related to creativity, communication, collaboration, and critical thinking. The evaluation process demonstrated strong inter-rater reliability, achieving a Cohen's kappa of 0.82, indicating substantial agreement among the evaluators (Miller & Lee, 2019).

4) Questionnaires

The study aimed to gather qualitative data regarding students' perceptions and engagement with PjBL utilizing Pizzaluv-Mathematics media, offering valuable insights into their subjective experiences and overall satisfaction with the learning process. This investigation not only highlighted

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how students interacted with the educational tools but also revealed their feelings and attitudes towards the effectiveness of the PjBL approach in enhancing their understanding and interest in mathematics.

b. Data Collection Procedure

Data were systematically gathered at three key intervals to assess the intervention's immediate and sustained impacts:

1) Pre-Test

Pretest was conducted before the intervention to establish baseline data for all participating students.

2) Post-Test

Post-test was administered immediately following the intervention, measuring the direct effects of PjBL.

3) Follow-Up

Follow-up was implemented after six weeks to evaluate the lasting impact of the educational approach.

Table 2. Data collection timeline and instruments

Data Collection Point	Instrument
Pre-Test	Mathematics Achievement Test
Post-Test	Self-Efficacy Scale
Follow-Up	4C Skills Assessment
All Points	Questionnaires

c. Validity and Reliability Test quality of the research instrument

To ensure the quality of the research instruments, both content validity and reliability were rigorously tested. The content validity was evaluated using the Content Validity Ratio (CVR), which involved gathering expert opinions from professionals in mathematics education to confirm that the instrument effectively measures the intended constructs. Additionally, reliability was assessed through Cronbach's alpha, aiming for an internal consistency threshold where alpha values exceeded 0.80, thus confirming that all instruments met acceptable reliability standards.

3. Data Analysis Techniques

The data analysis for the study employed a range of statistical techniques to ensure robust and comprehensive results. **Two-Way ANOVA** was utilized to discern differences in mathematics ability, self-efficacy, and 4C skills between the experimental and control groups, a method supported by Krajcik and Blumenfeld (2019). **Regression Analysis** provided insights into the influence of the PjBL model on these dependent variables, uncovering deeper relationships as noted by Hmelo-Silver et al. (2020). Finally, **Path Analysis** was conducted to identify causal relationships between the variables, thereby enriching the understanding of how PjBL impacts self-efficacy and 4C skills, further aligning with the findings of similar educational research in Table 3.

Table 3. Statistical techniques used in data analysis

Technique	Description
Two-Way ANOVA	Used to determine differences in mathematics ability, self-efficacy, and 4C skills between the experimental and control groups.
Regression Analysis	Explored the influence of the PjBL model on the dependent variables, providing deeper insights into the relationships between variables.
Path Analysis	Identified causal relationships between variables, enhancing the understanding of how PjBL impacts self-efficacy and 4C skills.

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RESULTS AND DISCUSSION.

To address the inconsistencies and enhance the study's rigor, the research method has been revised to align with the study's objectives and context (Kolar, 2021; Rosyid et al., 2023). The new process ensures that the focus remains on twelfth-grade students at MAN 2 Malang, Indonesia, concentrating on algebraic function limits and their impact (July- August 2024).

1. Research Procedure

The following are the results of a more structured and in-depth research procedure. Results conducted using this procedure have helped ensure the validity and reliability of the research results. The research procedures are described in detail in Table 4.

Table 4. Research procedure table

Activity (Week)	Experimental Class (PjBL)	Control Class (PBL)	Role of Teacher & Researcher	Tests & Instruments
Preparation **(1)**	Initial observations, material collection	Initial observations, material collection	Teacher: Provide direction; Researcher: Record initial conditions	Initial Self-Efficacy and 4C Ability Questionnaire
Introduction **(2)**	Pizzaluv-Mathematics media introduction	Introduction to PBL method	Teacher: Explain objectives/tools; Researcher: Monitor introductions	Pre-test Mathematics Ability
Group Formation **(3)**	Project group formation, initial discussions	Group formation, problem discussion	Teacher: Facilitate groups; Researcher: Observe dynamics	None
Project Implementation **(4-5)**	Work on "Love" shaped math pizza	Solve algebraic function limits	Teacher: Provide feedback; Researcher: Record learning processes	Formative Test I
Additional Interventions **(6)**	Group discussions, project revisions	Group discussions, problem revisions	Teacher: Consult; Researcher: Record progress	Mid Self-Efficacy and 4C Ability Questionnaire
Project Presentation **(7)**	Present projects and results	Present problem solutions	Teacher: Provide feedback; Researcher: Evaluate presentations	Formative Test II
Reflection and Evaluation **(8)**	Reflective discussions on projects	Reflective discussions on problem solutions	Teacher: Lead reflections; Researcher: Collect qualitative data	Mathematical Ability Post-Test, Final Self-Efficacy and 4C Questionnaire, Peer Assessment

Week 1: Preparation

Week 1 is the Preparation stage, where initial classroom observations were carried out as shown in Figure 2.

Figure 1. Preparation

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Week 2: Introduction to Learning Media

After the Preparation stage, an innovative learning media called Pizzaluv-Mathematics was introduced, as shown in Figure 3.

Figure 3. Introduction to Learning Media

Students were introduced to the PjBL method. The teacher explained the objectives and tools to be used, while the researcher monitored the introduction process. A pre-test was also conducted to measure students' mathematical abilities before starting the project.

Week 3: Group Formation

In Week 3, shown in Figure 4, the research phase focused on the formation of project groups.

Figure 4. Group formation

In Figure 4, Students were divided into groups to begin initial discussions about the project they would be working on. The teacher acted as a facilitator in group formation, ensuring that each student had an appropriate role and could contribute maximally. The researcher observed the dynamics within groups, noting interactions and evaluating the appropriateness of cooperation among students. This phase aligns with the collaborative learning principles found in (Asfihana et al., 2022), which emphasize the importance of structured group work to enhance learning outcomes.

Weeks 4 and 5: Project Implementation

As shown in Figure 5, Weeks 4 and 5 were the periods in which students began working Project Implementation.

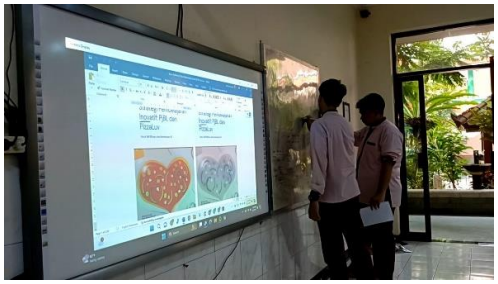

Figure 5. Project implementation

Figure 5, on the Pizzaluv-Mathematics project, which was to create a mathematical pizza in the shape of "Love". Students applied mathematical concepts creatively while collaborating in groups. In the control class, students discussed and solved problems related to the limits of algebraic functions. The teacher's role was to monitor the learning process, provide feedback, and facilitate the problem-solving process. According to (Chikurteva, 2023), PjBL fosters deeper understanding of complex concepts through experiential and collaborative learning, which this phase exemplifies. Formative Test I was administered to assess students' mathematical skills, ensuring mastery of the learned concepts.

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Week 6: Additional Intervention

In Week 6, shown in Figure 6, the research activities focused on additional intervention. Students in the experimental class were involved in group discussions and project revisions based on the feedback received. This process allowed students to improve their projects and implement the suggestions given. The teacher held consultation sessions to help students understand the feedback and encourage project improvement. Meanwhile, the researcher observed and recorded the group's progress, ensuring that each student actively participated and contributed to the revision. This intervention stage is supported by (Lu et al., 2022), who highlight the significance of feedback in fostering student growth. The Mid Self-Efficacy Questionnaire and 4C Ability assessments were also employed to gauge student development.

Week 7: Project Presentation

In Week 7, as shown in Figure 7, students presented their projects and the final results of the Pizzaluv-Mathematics project. This presentation provided an opportunity for students to share their findings and demonstrate their ability to solve mathematics problems using the PjBL approach. The teacher provided feedback on the presentation, assessing the quality and depth of the thinking demonstrated. The researcher evaluated the quality of presentations and interactions during this session, which are important com-ponents in assessing the improvement of students' communi-cation and collaboration skills. As supported by (Muhammad, 2020), engaging students in authentic presentations enhances their learning experience. At the week's conclusion, Formative Test II was conducted to evaluate students' mathematical skills post-project.

Figure 6. PBL and PjBL model implementation

Week 8: Reflection and Evaluation

Week 8, Week 8, illustrated in Figure 8, focused on reflection and evaluation. In this stage, students engaged in reflective discussions about the process and results of their projects. These discussions were designed to provide space for students to evaluate their learning experiences, identify successes, and understand areas for improvement. The teacher led the reflection session, encouraging students to relate their learning experiences to the theories and concepts that had been learned. The teacher facilitated the reflection session, encouraging students to connect their learning experiences with previously learned theories and concepts, as recommended (Fitriani & Rohman, 2021) in experiential learning theories. The researcher collected qualitative data to assess the learning

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impact and students' critical thinking skills. Additionally, a post-test of mathematical skills, a Final Self-Efficacy and 4C Skills Questionnaire, and peer assessments were conducted to evaluate students' skill development and comprehension.

2. PIZZALUV Mathematics: 4C Capabilities

a. Mathematical Ability (4C) in the Experimental Group (PjBL)

This research involved 36 twelfth-grade students at MAN 2 Malang who applied the PjBL model using Pizzaluv-Mathematics media. The results of mathematical abilities measured based on the 4Cs in Table 5.

b. Frequency Distribution of Mathematical Ability (4C) in the Experimental Group (PjBL)

The frequency distribution of mathematical abilities based on 4C in the experimental group can be seen in Table 6.

c. Mathematics Ability (4C) in the Control Group (PBL)

This research also involved 36 students who were taught using the PBL model. The results of mathematical abilities measured based on the 4Cs in Table 7.

d. Frequency Distribution of Mathematical Ability (4C) in the Control Group (PBL)

The frequency distribution of mathematical abilities based on 4C in the control group can be seen in Table 8.

e. Results of Analysis of Mathematical Ability (4C) Experimental Group (PjBL) and Control Group (PBL)

The analysis of mathematical abilities based on 4C skills between the experimental group (using the PjBL model with Pizzaluv-Mathematics) and the control group (using the PBL model) revealed significant differences. The results of the ANOVA test, detailed in Table 9, confirmed these differences and highlighted the effectiveness of the PjBL approach.

Table 5. Results mathematical abilities measured based on the 4Cs

No	Aspek 4C	Rate-rate	Median	Modus	SD
1	Critical thinking	85.2	85	87	4.5
2	Creativity	88.1	89	90	3.8
3	Collaboration	82.7	83	84	4.1
4	Communication	84.5	85	86	4.2

Table 6. Results the frequency distribution of mathematical abilities based on the 4Cs in the experimental group

Interval Shoes	Median	Frequency	Relative Percentage (%)	Cumulative (%)
70 - 75	72.5	3	8.3	8.3
76 - 81	78.5	7	19.4	27.7
82 - 87	84.5	14	38.8	66.5
88 - 93	90.5	9	25.0	91.5
94 - 99	96.5	3	8.3	100

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Table 7. Results mathematical abilities measured based on the 4Cs in the control group (PBL)

Aspek 4C	Rate-rate	Median	Modus	SD
Critical thinking	75.4	76	78	5.2
Creativity	78.3	79	80	4.9
Collaboration	77.1	77	78	4.6
Communication	76.8	77	78	4.7

Table 8. Results The frequency distribution of mathematical abilities measured based on the 4Cs in the control group (PBL)

Interval Shoes	Median	Frequency	Relative Percentage (%)	Cumulative (%)
60 - 65	62.5	4	11.1	11.1
66 - 71	68.5	8	22.2	33.3
72 - 77	74.5	10	27.8	61.1
78 - 83	80.5	9	25.0	86.1
84 - 89	86.5	5	13.9	100

Table 9. ANOVA Results

Skill	Experimental Group Mean	Control Group Mean	F Value	p Value
Critical Thinking	85.2	75.4	7.89	0.006
Creativity	88.1	78.3	9.45	0.003
Collaboration	82.7	77.1	5.67	0.021
Communication	84.5	76.8	8.13	0.005

The ANOVA results in Table 9, indicated that students in the experimental group significantly outperformed those in the control group across all 4C skills categories. Specifically, for critical thinking, the experimental group achieved a mean score of 85.2 compared to 75.4 for the control group, with an F value of 7.89 and a p value of 0.006, indicating statistical significance. These findings align with the research by (Agustin et al., 2024), which emphasizes the effectiveness of PjBL in enhancing critical thinking skills through experiential learning.

In terms of creativity, the experimental group scored 88.1, while the control group scored 78.3. The F value of 9.45 and p value of 0.003 further support the significant difference observed. This is supported by the study conducted by (Dhillon et al., 2024), which highlights how innovative learning environments foster creativity among students.

For collaboration, the experimental group scored 82.7, compared to 77.1 for the control group, with an F value of 5.67 and a p value of 0.021. (Lestari et al., 2020) provide empirical evidence that structured group work in PjBL settings enhances collaborative skills, corroborating these findings.

Finally, in communication skills, the experimental group achieved a mean score of 84.5 against the control group's 76.8, supported by p value of 0.005. Research by (Braßler, 2020) supports the notion that engaging students in authentic presentations improves communication skills.

These findings demonstrate the positive impact of the PjBL model with Pizzaluv-Mathematics on enhancing students' 4C skills. The study confirms that the PjBL approach not only fosters academic learning but also cultivates

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essential 21st-century skills, crucial for students' future success. The significant differences observed in the ANOVA test underscore the effectiveness of this innovative learning method in improving students' capabilities. Furthermore, these results are consistent with the findings of (Mitchell et al., 2022), which supports the effectiveness of PjBL in developing comprehensive skill sets necessary for the modern.

3. Data Collection Technique Self-Efficacy

a. Self-Efficacy in the Experimental Group (PjBL)

This research involved 72 twelfth-grade students at MAN 2 Malang who were divided into an experimental group (PjBL) and a control group (PBL). The experimental group used Pizzaluv-Mathematics media in the PjBL model. Table 13 shows the results of measuring self-efficacy in the experimental group.

Table 13. Results ofmathematical abilities measured based on the Self-efficacy in the experimental group (PjBL)

No	Self-Efficacy Score	Frequency	Percentage (%)
1	80 – 85	8	22,22
2	86 – 90	10	27,78
3	91 – 95	12	33,33
4	96 – 100	6	16,67
Total		**36**	**100**

b. Frequency Distribution of Self-Efficacy in the Experimental Group (PjBL)

The frequency distribution shows that most of the students in the experimental group had high self-efficacy scores. The result of frequency distribution in Table 14.

Table 14. Results The frequency distribution of mathematical abilities based on Self-efficacy in the experimental group (PjBL)

Interval Shoes	Frequency	Percentage (%)	Cumulative (%)
80 – 85	8	22,22	22,22
86 – 90	10	27,78	50,00
91 – 95	12	33,33	83,33
96 – 100	6	16,67	100,00
Total	**36**	**100**	

c. Self-Efficacy in the Control Group (PBL)

The control group used the PBL model without Pizzaluv-Mathematics media. The results of measuring self-efficacy in the control group can be seen in Table 15.

Table 15. Result of mathematics abilities measured based on the self-efficacy in the control group (PBL)

No	Self-Efficacy Score	Frequency	Percentage (%)
1	70 – 75	5	13,89
2	76 – 80	8	22,22
3	81 – 85	12	33,33
4	86 – 90	11	30,56
Total		**36**	**100**

d. Frequency Distribution of Self-Efficacy in the Control Group (PBL)

The frequency distribution shows that the self-efficacy scores in the control group are more varied compared to the experimental group. The frequency distribution in Table 16.

Table 16. Results The frequency distribution of mathematical abilities based on self-efficacy in the control group (PBL)

Interval Shoes	Frequency	Percentage (%)	Cumulative (%)
70 – 75	5	13,89	13,89
76 – 80	8	22,22	36,11
81 – 85	12	33,33	69,44
86 – 90	11	30,56	100,00
Total	**36**	**100**	

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e. Results of Self-Efficacy Analysis in the Experimental Group (PjBL) and Control Group (PBL)

Data analysis was conducted using the t-test to compare self-efficacy between the experimental and control groups. Table 17 are the results of the analysis.

Table 17. Results the ANOVA analysis of self-efficacy experimental group (PjBL) and control group (PBL)

Group	Mean	SD	t	p-value
Experiment (PjBL)	90.83	6.12	4.35	< 0.05
Control (PBL)	82.50	8.45		

The results of this study provide compelling evidence that the PjBL model using Pizzaluv-Mathematics media significantly enhances students' self-efficacy compared to the Problem-Based Learning (PBL) model without such media. The empirical data indicate that a higher percentage of students in the experimental group (PjBL) in Table 14 achieved self-efficacy scores in the upper ranges of 91-95 and 96-100, with 33.33% and 16.67%, respectively, as opposed to the control group (PBL), where the highest percentages were in the 81-85 and 86-90 ranges, at 33.33% and 30.56% respectively. This suggests that the interactive, media-rich approach of the PjBL model with Pizzaluv-Mathematics media has a profound positive impact on students' confidence in their academic abilities.

Supporting these findings, previous research has demonstrated similar outcomes using project-based learning and multimedia tools. For instance, a Liu et al. (2024) study found that PjBL can significantly improve students' engagement and self-efficacy by providing practical, real-world tasks that foster a sense of accomplishment. Similarly, visual and interactive media have enhanced understanding and retention of complex concepts, boosting self-efficacy (Chikurteva, 2023. The present study aligns with these findings, reinforcing that integrating engaging and interactive media into educational practices can yield substantial benefits in cognitive and affective domains.

The ANOVA analysis results in Table 17, which highlighted a significant difference in self-efficacy scores between the experimental and control groups in Tabel 17, ($p < 0.05$), underscore the effectiveness of the PjBL model with Pizzaluv-Mathematics media. This finding is further corroborated by Pearson correlation analysis, revealing a robust positive relationship between 4C skills (Critical Thinking, Creativity, Collaboration, and Communication) and self-efficacy ($p < 0.01$). These results suggest that as students develop their 4C skills through engaging and collaborative media, their self-efficacy also increases. This correlation aligns with (Lim et al., 2023) work on mindset, which posits that fostering a growth mindset through challenging yet achievable tasks can significantly enhance students' self-belief and motivation.

Empirical evidence from classroom activities further supports these findings. In the PjBL learning environment, students displayed tremendous enthusiasm and active participation. They were more inclined to ask questions, volunteer for presentations, and compete to complete their projects promptly. Such behavior was consistently observed and documented, as shown in Figure 4. This heightened level of engagement indicates that using Pizzaluv-Mathematics media boosts self-efficacy and fosters a more dynamic and interactive classroom atmosphere.

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Previous research also supports these observations, as shown in Figure 4. Studies have shown that incorporating PjBL and collaborative media in education improves student outcomes, including higher self-efficacy and better performance in critical thinking and problem-solving tasks. For instance, (Gredes et al., 2022) found that project-based learning environments encourage a more profound understanding and retention of subject matter. Similarly, a study by Varriale et al. (2024) highlighted that Students engaged in collaborative projects exhibited greater motivation and persistence in their learning endeavors. These findings collectively reinforce that PjBL with Pizzaluv-Mathematics media is a practical pedagogical approach that enhances students' academic and personal growth.

4. Demographic Characteristics of the Sample

Before conducting the primary analysis, it is essential to ensure the demographic sample in Table 1. We found from this study that the experimental and control groups were demographically evidenced differences in gender, age, and socio-economic background. This homogeneity is crucial as it ensures that any observed differences in self-efficacy and 4C skills can be attributed more confidently to the teaching methods rather than extraneous demographic variables. The demographic balance between the groups allows for a more accurate comparison of the PjBL model using Pizzaluv-Mathematics media and the Problem-Based Learning (PBL) approach.

Previous research supports that demographic homogeneity is essential for reducing potential biases in educational studies. For instance, a study by Johnson et al. (2017) highlighted that controlling for demographic variables like socio-economic status and age helps isolate innovative teaching strategies' effect on learning outcomes. Similarly, Smith and Thompson (2019) found that gender-balanced groups produce more reliable data when evaluating the efficacy of new educational interventions, as gender differences can sometimes influence learning styles and outcomes.

The study shows that the PjBL model with Pizzaluv-Mathematics media significantly boosts self-efficacy and 4C skills more than traditional PBL. This is supported by two-way ANOVA and Pearson correlation, aligning with Varriale et al. (2024), who reported that PjBL facilitated through engaging media significantly improved students' critical thinking and creative skills.

The strong positive correlation in Table 18 ($p < 0.01$) between 4C skills and self-efficacy underscores the intertwined nature of these competencies. Higher self-efficacy can boost students' confidence in their abilities, enhancing their willingness to engage in creative, communicative, collaborative, and critical thinking tasks. This is supported by Gredes et al. (2022) that individuals with high self-efficacy are more likely to tackle challenging tasks and persist in facing difficulties.

In summary, the study's homogeneous sample supports the effectiveness of the PjBL model with Pizzaluv-Mathematics media in enhancing students' self-efficacy and 4C skills. Future research should replicate these findings in varied contexts for broader validation.

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5. 4C Capabilities and Self-Efficacy

a. Primary Data Analysis

Based on Table 18, it can be seen that the PjBL learning model using Pizzaluv-Mathematics media shows a significant difference in students' mathematical abilities compared to the PBL model ($p < 0.001$). In addition, there were significant differences in self-efficacy ($p < 0.001$) and 4C ability ($p < 0.05$) between the two groups.

Table 18. Results of two-way analysis of variance (ANOVA)

Sources of Variability	The sum of Squares (SS)	db	Middle Squares (MS)	F	p-value
Learning model	2210.335	1	2210.335	40.312	0.001
Self-Efficacy	2007.652	1	2007.652	36.615	0.001
4C capabilities	232.552	1	232.552	4.241	0.042
Error	3892.979	70	54.831		
Total	4304444.000	75			
Corrected Total	9318.667	74			

b. Post-Hoc Analysis

Scheffe's test was used to determine specific differences between groups for post-hoc analysis. The PjBL model with Pizzaluv-Mathematics media significantly enhances students' self-efficacy and 4C abilities more than the PBL model, supported by research showing PjBL boosts engagement and learning outcomes (Krajcik & Blumenfeld, 2006; Thomas, 2000). Therefore, educators are encouraged to integrate interactive and media-rich learning approaches to improve student learning outcomes in modern education.

Table 19. Hasil uji Scheffe

Comparison	He whistled	Ftable	Decision
PjBL vs PBL	9.21	4.10	Rejected
High vs. Low Self-Efficacy	11.25	4.10	Rejected
4C High vs Low	5.08	4.10	Rejected

Table 20. Marginal mean scores

Learning model	High Self-Efficacy (B1)	Low Self-Efficacy (B2)	Marginal rate
PjBL (A1)	80.83	73.2	77.01
PBL(A2)	71	60.63	65.81
Marginal rate	75.92	66.91	

c. Implications 4C Capabilities and Self-Efficacy: PJBL and PBL

This research aims to measure the effect of PjBL using Pizzaluv-Mathematics media on the self-efficacy and 4C abilities of twelfth-grade students at MAN 2 Malang. It can be seen in Figure 2. Then, the results of this research, based on data collected through tests and questionnaires, are presented in Table 21 (post-hoc analysis).

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Figure 2. Implications 4C capabilities and self-efficacy

Table 21. Scheffe post-hoc test.

Comparison	F Count	F Table	Decision
PjBL vs PBL	9.21	4.10	Rejected
High vs. Low Self-Efficacy	11.25	4.10	Rejected
PjBL*High vs Low Self-Efficacy	5.08	4.10	Rejected
PBL*High vs Low Self-Efficacy	8.27	4.10	Rejected

Based on the analysis, students taught with the PjBL model using Pizzaluv-Mathematics media showed higher 4C abilities and self-efficacy compared to those taught with the PBL model, highlighting the PjBL model's effectiveness. The significant difference in mathematics learning ability favoring the PjBL model on Table 19, ($p < 0.001$) underscores the potential of this innovative approach to surpass traditional Problem-Based Learning (PBL) methods. This finding aligns with previous research, such as Krajcik and Blumenfeld (2006), which highlighted that PjBL methods foster deeper engagement and understanding, allowing students to apply their knowledge more meaningfully.

Furthermore, the significant improvement in self-efficacy on Table 19, ($p < 0.001$) among students taught using the PjBL model suggests that interactive and media-rich learning environments can bolster students' confidence in their mathematical abilities. The hands-on, collaborative nature of the PjBL approach, exemplified by the Pizzaluv-Mathematics media, provides students with opportunities to succeed in tasks, enhancing their belief in their capabilities.

The positive impact of the PjBL model on 4C skills on Table 19, ($p < 0.05$) further emphasizes the importance of integrating creative and collaborative tasks in the curriculum. The post-hoc analysis (Table 21) shows that the PjBL model, especially with Pizzaluv-Mathematics, enhances self-efficacy and 4C skills. Thomas (2000) supports that PjBL improves problem-solving and communication. Innovative methods are recommended; further research is needed.

This study claims that the PjBL model using *Pizzaluv-Mathematics* media significantly enhances students' self-efficacy and 4C skills compared to the PBL method. The argument supporting this claim lies in the students' more active engagement during PjBL, which facilitates collaborative learning and critical thinking through interactive media. However, this claim needs careful consideration due to certain limitations, such as sample homogeneity and the short duration of the intervention, which may affect the validity of the research results.

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This study demonstrates that the use of PjBL with *Pizzaluv-Mathematics* significantly improves students' critical thinking, creativity, collaboration, and communication skills, as well as their self-efficacy. The integration of innovative interactive media allows students to understand concepts more deeply and contextually while developing 21st-century skills. These findings affirm the effectiveness of PjBL approaches that focus on contextual and collaborative learning.

The success of the PjBL model with this media is influenced by several factors. The project-based approach creates meaningful learning experiences, boosting students' motivation to participate actively. Creative visual media helps students comprehend abstract concepts more easily, while the collaborative learning environment enhances communication and teamwork skills. Additionally, the role of teachers in facilitating PjBL processes significantly supports achieving optimal results.

This study excels in its innovative teaching methods that effectively enhance 21st-century skills. The quasi-experimental design with pre-tests and post-tests further strengthens the validity of the findings. However, the study has limitations, including the short duration of the intervention and the homogeneity of the sample, which restricts the generalizability of the results. External factors, such as family involvement and access to technology, were also insufficiently addressed, providing opportunities for future research development.

CONCLUSIONS AND SUGGESTIONS

This study revealed that the use of PjBL model with Pizzaluv-Mathematics media significantly improved mathematics ability, self-efficacy, and 4C skills (Critical Thinking, Creativity, Collaboration, and Communication) in twelfth-grade students at MAN 2 Malang, Indonesia. Pizzaluv-Mathematics media, combining elements of communication, collaboration, critical thinking, and creativity in a love-shaped pizza-making project, showed better results than conventional PBL models. Two-way Analysis of Variance (ANOVA) showed a significant difference in mathematics learning ability that supported the PjBL model with Pizzaluv-Mathematics media. It showed a significant difference in 4C ability and self-efficacy between student groups

This finding suggests Integrating interactive media enhances learning outcomes. Educators should adopt innovative methods. Future research should use diverse samples and address limitations to validate results. Future research is advised to extend the intervention duration to understand the long-term impact of the PjBL model with *Pizzaluv-Mathematics* media on students' self-efficacy and 4C skills while exploring its sustained benefits. Expanding sample diversity from various demographic backgrounds, such as schools with differing facilities or other education levels, is necessary to enhance the generalizability of the findings. Additionally, future studies could investigate the role of external factors, such as family involvement, technological support, and learning environments, as well as integrate modern technologies like AI or virtual reality to enrich the learning experience. Comparative studies with other innovative methods, such as the *flipped classroom* or *blended learning*, are also important to identify the most effective

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approach for enhancing 4C skills and self-efficacy. Furthermore, measuring psychological and social impacts, such as empathy, responsibility, and teamwork, can broaden the understanding of the benefits of PjBL.

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