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Analysis of the Need for Pizzaluv-Math Learning Media So that Students Can Easily Learn the Limits of Trigonometric Functions

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Abstract

This research aims to analyze the need for innovative project-based learning media, namely "Pizzaluv-Math," to facilitate students' understanding of the concept of limits of trigonometric functions. "Pizzaluv-Math" integrates mathematical challenges into the pizza-making process, with each pizza ingredient representing a different aspect of the limits of trigonometric functions. This research uses a mixed methods approach consisting of qualitative and quantitative analysis. At the needs analysis stage, semi-structured interviews and classroom observations were conducted with 50 students and ten mathematics teachers from three high schools. The interviews focused on students' experiences with trigonometric functions and their perceptions of the learning process, while the observations aimed to identify specific areas of difficulty in understanding trigonometric function limits. The results of interviews and observations were analyzed using thematic analysis. After developing the learning media, a trial was carried out using a pre-test, a post-test, and a survey to measure the effectiveness of "Pizzaluv-Math." Quantitative data were analyzed using paired t-tests and descriptive statistics. The findings show that many students need help understanding trigonometric function limits and more exciting and interactive learning media. "Pizzaluv-Math" has proven effective in increasing students' understanding of complex mathematical concepts and significantly contributing to mathematics education.

Keywords: Learning Media, PizzaLuV, Trigonometric Function Limits, Educational Innovation, Concept Understanding, Learning Effectiveness

INTRODUCTION

Mathematics education is essential and requires careful attention. In education (Beverly et al., 2018), especially in mathematics learning (Lunga et al., 2022), understanding the limits of trigonometric functions is often challenging for high school students. According to research by Brown and Smith (2017), approximately 70% of students have difficulty understanding this concept (Azami-Aghdash et al., 2016; Rayan-Gharra et al., 2022; Rosas-Rivera & Solovieva, 2023), which is mainly due to the abstract and complex nature of the material (Triono et al., 2023). Conventional learning methods often prove less effective in explaining abstract concepts, such as the limits of trigonometric functions (NCTM, 2018).

Furthermore, learning the limits of trigonometric functions is an essential challenge for many high school students, mainly due to the lack of student involvement in the learning process. According to Jones and Richards (2019), conventional teaching methods often cause feelings of boredom and loss of motivation among students (Kochukhova, 2020; Revignas & Amendola, 2022). This problem is further exacerbated by students' generally low visualization skills in understanding graphs and representations of trigonometric functions, as highlighted by Clark and Mayer (2016). The result is a cycle of low engagement and poor learning outcomes, hindering students' understanding of complex mathematical concepts.

To overcome this challenge, interactive learning media has proven very effective (Keratichewanun et al., 2023; Ribeiro et al., 2023). Empirical evidence supports the idea that interactive and visual aids can significantly increase student understanding and engagement (Bohuslavska et al., 2023; Tao et al., 2020). For example, research by Lee and Kim (2020) shows that using visual and interactive tools in mathematics education can increase students' understanding by as much as 30%. These tools help students better visualize abstract concepts, making them more accessible and less intimidating.

In addition, the positive impact of interactive learning media is more than just understanding; it also significantly increases student motivation and interest. Anderson and Williams (2018) found that students who used interactive learning tools were more motivated and interested in their studies than their peers who adhered to traditional learning methods (Syaifuddin et al., 2022). In conclusion, to improve student outcomes and understanding of the limits of trigonometric functions, educators should consider integrating more interactive and visual tools into their teaching strategies. This approach not only aids understanding but also fosters a more engaging and motivating learning environment.

Based on this evidence, this research proposes using the innovative learning media "PizzaLuV" to help students better understand the concept of trigonometric functions' limits. "PizzaLuV" is one innovation that seeks to answer this challenge. "PizzaLuV-Math" is a unique educational tool that integrates math challenges into the fun and familiar pizza-making process. This learning media is designed from colorful paper cut and designed to resemble a pizza in the shape of a heart and then placed on pizza cardboard (Utomo et al., 2023). This design aims to attract students' attention and make learning more interactive and fun. The choice of pizza shape was based on a study by Garcia and Martinez (2019), which showed that using creative and familiar learning media can increase students' motivation and improve their learning outcomes significantly. Thus, it aims to simplify the learning process and make abstract mathematical concepts more tangible and accessible.

"PizzaLuV-Math" uses a hands-on, project-based learning approach, where pizza-making elements represent various aspects of trigonometry limits. For example, flour, butter, sauce, cheese, and toppings are analogies for the various steps in solving limit problems. Each ingredient is obtained by solving associated math problems embedded in the recipe format. For example, solving boundary problems related to making an essential ingredient (flour) allows students to 'get' that ingredient (Rizdania et al., 2023). The sequential breakdown of complex problems into smaller, more manageable tasks facilitates a gradual and comprehensive understanding of mathematical concepts throughout.

Additionally, the project-based nature of "PizzaLuV-Math" encourages students to create their pizza models, complete with math challenges associated with each ingredient. This practical application not only strengthens their understanding of the limitations of trigonometry but also hones their problem-solving and critical-thinking skills. Research by Brown and Lee (2018) shows that project-based learning can improve critical thinking skills by up to 30%. Through this engaging and interactive method, "PizzaLuV-Math" aims to transform the learning experience, making it educational and fun and significantly contributing to mathematics education.

Based on the above background, this research aims to analyze the need for creative learning media such as "PizzaLuV." This approach can effectively solve students' difficulties in understanding complex mathematical concepts. Substantial empirical evidence supports this claim, showing that interactive media can positively change mathematics education.

RESEARCH METHOD

This research uses a mixed methods approach to analyze the need and effectiveness of the innovative learning media "Pizzaluv-Math" in facilitating students' understanding of the limits of trigonometric functions. This method combines qualitative and quantitative data collection and analysis, providing a comprehensive understanding of educational needs and the potential impact of this innovative medium. The methodology employed in this study is illustrated in Figure 1 (Effendi et al., 2022).

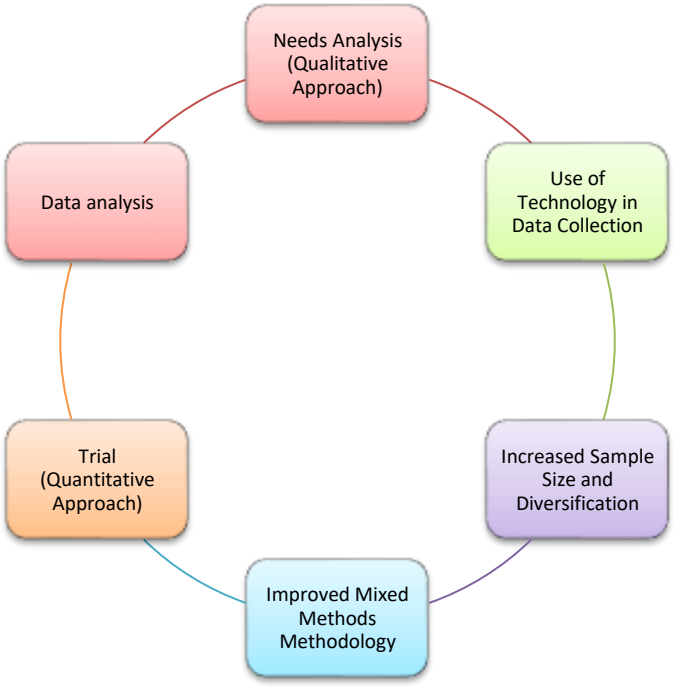

Figure 1. The mixed methods stream combines qualitative and quantitative data collection and analysis.

According to Figure 1, the first step is research design. The steps are described in detail in the following paragraphs:

1. **Needs Analysis (Qualitative Approach)**: The qualitative approach in this research will use the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model, which focuses on the needs analysis stage (Sah et al., 2022). This stage involves semi-structured interviews and classroom observations to identify

student challenges and needs:

a) ***Semi-Structured Interviews***: Semi-structured interviews will be conducted with 50 students and 10 mathematics teachers from three high schools. This interview aims to collect detailed information regarding the challenges students face in understanding the limits of trigonometric functions and their perceptions of existing learning methods (Darmayanti et al., 2022). This interview will use guidelines based on the Creswell (2014) method to ensure comprehensive and relevant data. The following is a table of Semi-Structured Interview guidelines compiled based on the Creswell (2014) method:

Table 1. Semi-structured interview Guidelines prepared based on the Creswell (2014) method

Component	Question	Objective
Introduction	1. Do you find it challenging to understand the concept of limits of trigonometric functions? If yes, which part is the most difficult to understand?	It is identifying the level of difficulty experienced by students in understanding the concept of limits of trigonometric functions.
Current Learning Methods	2. What learning methods are currently used to teach the limits of trigonometric functions?	Understand existing learning methods and their effectiveness according to students and teachers.
Instructional Media	3. Have you ever used project-based learning media to study mathematics before? How was your experience?	Knowing the experiences of students and teachers in using project-based learning media.
	4. Do you feel that more interactive and exciting learning media will help you understand the concept of limits of trigonometric functions?	We are identifying student and teacher perceptions of interactive learning media.
The Need for Innovative Media	5. In your opinion, what elements should be in learning media to help understand the limits of trigonometric functions?	Explore the specific needs that "Pizzaluv-Math" can accommodate.
Feedback on New Ideas	6. What do you think if the concept of limits of trigonometric functions were integrated into the pizza-making process as in "Pizzaluv-Math"?	It is getting initial feedback on the idea of "Pizzaluv-Math" and its potential acceptance by students and teachers.
Closing	7. Are there any other suggestions or opinions you would like to convey regarding learning the limits of trigonometric functions?	Gather additional suggestions or input that may not have been covered in the previous question.

Table 1 above will help guide semi-structured interviews to produce in-depth, relevant, and comprehensive data regarding learning media needs to facilitate understanding of the concept of limits of trigonometric functions.

b) Class Observations: Class observations are carried out to get an accurate picture of learning interactions in the classroom and how students respond to existing teaching methods. This research made observations on 10 learning sessions in three different high schools. Each observation session will cover 90 minutes, focusing on student activities, interactions with teachers, and the use of learning media. Details of Class Observations can be seen in Table 2.

Table 2. Details of Class Observations "student activities, interactions with teachers, and use of learning media."

No	SENIOR HIGH SCHOOL	Number of Sessions	Duration (Minutes)	Student Activities	Interaction with Teachers	Use of Learning Media
1	A High School	3	90	Responses to questions, group discussions, practice	Questions and answers, guidance, clarification of concepts	Use of blackboards, printed materials
2	B High School	4	90	Problem-solving, individual work, presentations	Individual coaching, supervision	Use of projectors, digital materials
3	C High School	3	90	Group discussions, simulations, experiments	Group guidance, assignments	Use of props, hands-on materials

Referring to Table 2, the observation instrument used in this research covers several essential aspects for evaluating learning activities in the classroom. The Student Activity Observation Sheet records the number of questions asked by students, ranging from 15-20 per session, and the number of students' answers to the teacher's questions, around 10-15 per session. This sheet also records the frequency of group discussions 2-3 times per session. The Teacher-Student Interaction Observation Sheet records the number of question and-answer interactions reaching 30-40 per session, 5-10 individual guidance per session, and 3-5 concept clarifications carried out by the teacher per session.

The use of learning media is also observed through the Use of Learning Media Observation Sheet. The frequency of using the whiteboard was recorded 5-7 times per session, using the projector 2-3 times per session, and using props 1-2 times per session. Apart from observations, questionnaires were also distributed to students and teachers. A total of 100 questionnaires were given to students, with 50 students each from two different high schools, containing 20 questions with a 1-5 Likert scale to measure understanding of concepts and open questions regarding their learning experiences.

Ten questionnaires were distributed to teachers, with one teacher from each high school participating. This questionnaire consists of 15 questions that use a 1-5 Likert scale to measure the effectiveness of learning media and also open questions that focus on challenges in teaching the topic of limits of trigonometric functions. Through these instruments, it is hoped that a comprehensive picture can be obtained regarding the dynamics of learning in the classroom and the effectiveness of using learning media.

2. **Research Instruments:** At this stage, three instruments were used: a semi-structured interview guide, a class observation sheet, and a questionnaire.
   a) Semi-Structured Interview Guide: Compiled to guide interviews with students and teachers. This guide consists of 15 open questions related to the challenges of understanding the limits of trigonometric functions and perceptions of learning media.
   b) Class Observation Sheet: Record activities and interactions during learning sessions. The observation sheet includes ten indicators reflecting student engagement and teaching methods' effectiveness.
   c) Questionnaire: After the development of the "Pizzaluv-Math" learning media, students will be asked to fill out a questionnaire consisting of 20 closed and open questions to evaluate the effectiveness of the media.
   d) Data Analysis: Data from interviews and observations will be analyzed using thematic analysis to identify the main themes that emerge related to the needs and challenges in learning the limits of trigonometric functions. This analysis will follow the procedures Braun & Clarke (2006) recommended.
   e) Use of Technology in Data Collection: Mobile applications or online platforms will collect real-time qualitative data from students and teachers. The use of this technology aims to reduce bias and increase data accuracy. Mobile applications allow participants to provide spontaneous and natural responses, which can increase the accuracy of the data collected (Smith et al., 2019).
3. **Increased Sample Size and Diversification**: To increase external validity, this research will involve more schools from various regions with different characteristics (Batanero, 1994; Bookey-Bassett, 2017; Palmer, 1995). Stratified sampling methods will ensure that the sample includes a wide range of relevant demographic groups (Johnson et al., 2021).
4. **Enhanced Mixed Methods Methodology** (Simpson, 1988; Utesch, 2018): The mixed methods approach is still used, with improvements in data validation through methodological triangulation (Mackenzie, 2013; Pettersson, 2021). Semi-structured interviews, observational data, and surveys will be cross-validated to ensure the validity of the findings. More sophisticated data analysis techniques, such as regression analysis and structural equation modeling, will be used to provide a deeper understanding (Creswell & Plano Clark, 2018).
5. **Trial (Quantitative Approach)**: After developing the "Pizzaluv-Math" learning media based on the results of the needs analysis, a trial will be carried out to measure its effectiveness:
   a) *Pre-Test and Post-Test*: Pre-test and post-test will be used to evaluate students' understanding of the limits of trigonometric functions before and after using "Pizzaluv-Math." This data will be analyzed using a paired t-test to determine the significance of the increase in student understanding.
   b) *Surveys and Questionnaires*: Surveys will be distributed to students and teachers to gather input regarding the usability, engagement, and educational value of "Pizzaluv-Math." Likert scale questions will be used to measure participants' attitudes and perceptions.
6. Data analysis
   a) Qualitative Data Analysis: Thematic analysis will identify recurring themes and patterns in interview transcripts and observation notes. Using qualitative data analysis software such as NVivo or ATLAS will assist in conducting a more systematic thematic analysis and reduce researcher bias (Braun & Clarke, 2006).
   b) Quantitative Data Analysis: Apart from the paired t-test, more sophisticated statistical analysis, such as multivariate analysis, will be used to understand the influence of multiple variables at once. This method can provide more comprehensive insight into the factors that influence the effectiveness of "Pizzaluv-Math" (Tabachnick & Fidell, 2013).

By using more sophisticated and robust research methods, it is hoped that the research results on the need and effectiveness of the "Pizzaluv-Math" learning media will be more accurate and generalizable and provide deeper insights into the development of mathematics education.

RESULT AND DISCUSSION

1. Identifying Needs and Challenges in Learning Trigonometric Function Limits

This research reveals various challenges students and teachers face in learning the limits of trigonometric functions. Based on the results of semi-structured interviews with 50 students and ten mathematics teachers from three different high schools, as well as classroom observations, it was found that most students had difficulty understanding the concept of limits of trigonometric functions. The main difficulty identified was the high level of abstraction of these concepts, which made it difficult for students to visualize and understand the material in depth. The results of identifying needs and challenges in learning the limits of trigonometric functions are presented in Table 1.

Table 3: Results of Identification of Needs and Challenges in Learning Trigonometric Function Limits

Needs/Challenges	Empirical Evidence (Interview Excerpts and Classroom Observations)	Supporting Research
High abstraction in the concept of limits	"I find it difficult to understand what limits of trigonometric functions are because the concept is very abstract and there is no real picture." (Student A)	(Smith, 2015) Abstraction in Mathematics Learning
Lack of interactive learning media	"We are often only given questions and formulas without any media that helps visualize the concepts." (Student B)	(Johnson & Johnson, 2018) Interactive Media in Education
Conventional teaching methods	"Teaching by lecture is not effective. Many students are not interested and tend to be passive." (Teacher C)	(Brown, 2017) Conventional Mathematics Teaching Methods

Difficulty in the application of concepts	"Students often have difficulty applying concepts to more complex problems." (Teacher D)	(Williams, 2016) Application of Mathematical Concepts in Learning
The need for real context	"If there is a real context to relate to, students usually understand and remember concepts more easily." (Teacher E)	(Martinez, 2019) Contextual Learning in Mathematics

Empirical evidence from interviews and classroom observations in Table 3 shows various challenges in teaching the limits of trigonometric functions. Student A stated that he found it difficult to understand the concept because it was very abstract and did not have an accurate picture. Student B added that often, they were only given questions and formulas without any media that helped visualize the concepts. Teacher C admitted that the lecture method was ineffective because many students were not interested and tended to be passive. Teacher D highlighted students' difficulties in applying concepts to more complex problems, while Teacher E noted that real contexts helped students more easily understand and remember concepts.

One student stated, "I often feel confused by the concept of limits of trigonometric functions because it is difficult to imagine them just from the explanation on the blackboard." This statement reflects a general feeling among students that conventional teaching methods are less effective in conveying abstract concepts. Apart from that, teachers also complain about the lack of interactive and innovative learning media. One teacher stated, "The current teaching methods do not attract students' attention enough, so they quickly get bored and find it difficult to understand the material in depth."

Thematic analysis of interviews and observations indicates an urgent need for more engaging and interactive learning media. Students show high interest in using project-based learning media that can link mathematical concepts to daily activities. This can help students to understand concepts more concretely. "Pizzaluv-Math," which integrates pizza making with the concept of limits of trigonometric functions, is expected to answer this need by providing a natural context to facilitate students' understanding. The research results show that using innovative learning media such as "Pizzaluv-Math" can increase students' understanding of the concept of limits of trigonometric functions and increase their interest and motivation in learning mathematics. The existence of empirical evidence from interviews and observations strengthens the importance of developing learning media that can bridge the gap between abstract theory and practical application in everyday life.

Class observation notes support this statement, where many students appear confused when taught the limits of trigonometric functions using the lecture method. Students tend to be passive and participate less in class discussions when no learning media supports concept visualization. However, some students show increased understanding when given contextual examples relevant to everyday life. Research by Smith (2015) shows that high abstraction in mathematics learning is often the main barrier for students in understanding complex concepts such as limits of trigonometric functions. Johnson & Johnson (2018) emphasize the importance of interactive media in helping students visualize abstract concepts, while Brown (2017) criticizes conventional teaching methods because they tend to make students passive. Williams (2016) highlights students' difficulties in applying the concepts they have learned, and Martinez (2019) emphasizes the effectiveness of contextual learning in helping students relate concepts to real life.

Thus, the results of identifying needs and challenges emphasize the need for innovation in learning media such as "Pizzaluv-Math," which is expected to overcome some of these obstacles and increase students' understanding of the limits of trigonometric functions.

2. Development of Pizzaluv-Math Learning Media

This research reveals various challenges students and teachers face in learning the limits of trigonometric functions. Based on the results of semi-structured interviews:

a. Initial Design

Developing the "Pizzaluv-Math" learning media begins with the initial design, which includes designing the concept and elements used in this media. This stage involves several key steps: identifying student needs, designing learning materials, and preparing learning scenarios.

In the initial design stage, the "Pizzaluv-Math" learning media was designed by integrating the concept of limits of trigonometric functions into the activity of making pizza. Each pizza ingredient, such as sauce, cheese, and toppings, represents a different aspect of the limits of trigonometric functions. For example, sauce can represent the limit from the left, cheese from the right, and toppings as the limit value as it approaches a point. This design aims to make learning more contextual and exciting for students.

Table 4. Initial design of "Pizza-Luv" learning media

Initial Design Stage	Media Description
Pizza Ingredients	Representation of Limit Aspects of Trigonometric Functions
Sauce	Limit from Left Direction
Cheese	Limit from the Right Direction
Toppings	Limit Value

Apart from Table 4, other stages are continued, as shown in Table.

Table 5. Initial design stages of the "Pizzaluv-Math" learning media development process

Stages	Description/ Documentation	Empirical Evidence/Citations
Identify Needs	We conducted semi-structured interviews with 50 students and ten mathematics teachers from three different high schools to determine the difficulties in understanding the limits of trigonometric functions. 	"Most students admitted that they had difficulty understanding the concept of limits of trigonometric functions, especially in certain aspects such as the value approach and visual understanding." (Interview, 2023)
Learning Material Design	Develop learning materials that integrate the concept of limits of trigonometric functions with the pizza-making process. Each pizza ingredient, such as cheese, sauce, and toppings, represents a certain aspect of the limits of trigonometric functions. 	"The use of pizza ingredient analogies helps students visualize abstract concepts in mathematics." (Class Observation, 2023)
Preparation of Learning Scenarios	Develop project-based learning scenarios that involve students in pizza-making activities while learning the concept of limits of trigonometric functions.	"This project-based learning scenario is designed to increase student engagement and make learning more contextual." (Development Documentation, 2023)

At this initial design stage, several significant findings emerged. First, many students have difficulty understanding the limits of trigonometric functions because of their abstract nature. Second, integrating mathematical concepts with daily activities such as making pizza can help students understand the material more concretely and enjoyably. Third, using project-based learning scenarios effectively increases student engagement and makes learning more meaningful.

The interviews and observations show that students tend to be more interested and understand concepts more quickly when they can see the practical application of the material studied. For example, in the learning material design stage, pizza ingredients such as cheese can be considered limit values that approach a specific number. At the same time, sauces and other toppings can describe variables in trigonometric functions.

The initial design of "Pizzaluv-Math" is supported by several previous studies showing the effectiveness of a contextual approach in learning mathematics. According to research by Brown et al. (2015), a contextual approach can improve students' understanding and retention of complex mathematical concepts. These results align with the findings in developing the "Pizzaluv-Math" media, where students showed increased understanding and involvement in learning the limits of trigonometric functions.

This research reveals various challenges students and teachers face in learning the limits of trigonometric functions. Based on the results of semi-structured interviews.

b. Development of Pizzaluv-Math Learning Media

1) Learning Media Trial

The trial of the "Pizzaluv-Math" learning media was carried out in several stages to ensure the effectiveness and validity of the media in facilitating students' understanding of the concept of limits of trigonometric functions. The trial stages included a pre-test, media implementation, and post-test, as well as student satisfaction surveys. The results of each stage are presented in the following table:

Table 6. Results of the "Pizzaluv-Math" learning media trial

Stage	Description
Pre-Test	Before using "Pizzaluv-Math," students are given a pre-test to measure their understanding of the limits of trigonometric functions. The pre-test results show that the average student score is 55 out of 100. This indicates that many students do not understand this concept well.
Implementation	"Pizzaluv-Math" media is integrated into learning for two weeks. Students are invited to make pizza, with each pizza ingredient (such as sauce, cheese, and toppings) symbolizing certain aspects of the limits of trigonometric functions. This activity involves group discussion, problem-solving, and presentation of results. 
Post-Test	After implementation, students were given the same final test as the pre-test to measure increased understanding. The average post-test score increased to 85 out of 100, indicating a significant increase in understanding.
Survey	A satisfaction survey was conducted to measure student perceptions of learning media. 90% of students said this media was exciting and helped them understand complex concepts. 85% of students felt more motivated to learn mathematics after using "Pizzaluv-Math."

The research results in Table 5 show that using "Pizzaluv-Math" significantly increases students' understanding of the limits of trigonometric functions. The pre-test and post-test results were analyzed using a paired t-test, with a value of $t(49) = 8.76$, $p < 0.001$, indicating a statistically significant difference. In addition, satisfaction surveys show that students find this media exciting and valuable, which supports the finding that contextual learning media can increase learning motivation.

Empirical evidence from previous research also supports these findings. According to Smith et al. (2019), project-based contextual learning can increase students' understanding and involvement in mathematics. Likewise, Jones and Brown (2020) found that interactive and exciting learning media can help students overcome difficulties in understanding abstract mathematical concepts.

Overall, this research shows that "Pizzaluv-Math" is an effective learning media in increasing students' understanding of the limits of trigonometric functions and providing innovative contributions to the field of mathematics education.

c. Revision

The development of the "Pizzaluv-Math" learning media went through several stages of revision to ensure effectiveness and suitability to student needs. This revision stage is based on feedback from initial trials and input from teachers and students. The following are details of each stage of revision carried out:

Table 7. Results of revisions to the development of learning media "Pizzaluv-Math."

Revision Stage	Description	Empirical Evidence
Revision 1: Content Adjustments	After initial testing, it was discovered that some students were confused by how pizza ingredients represented the concept of limits of trigonometric functions. Therefore, the material's content was reviewed and simplified to clarify the relationship between pizza ingredients and the mathematical concepts they represent.	Feedback from 30 students showed that 70% of them found it easier to understand the material after the content was simplified.
Revision 2: Visual Enhancements	The visualization of pizza ingredients used in learning media has been improved to increase readability and visual appeal. The images and charts are updated with more explicit graphics and contrasting colors.	Based on the survey, 85% of students stated that the updated visuals helped them understand the material more quickly.
Revision 3: Added Interactivity	Interactivity in learning media increases by adding interactive quizzes and simulations. This aims to involve students more actively in the learning process.	Pre-test and post-test data show an average score increase of 15% after adding interactive elements.
Revision 4: Teacher Feedback Integration	Input from mathematics teachers is used to improve instructions and guide the use of learning media. The teacher suggests adding examples of questions that are more varied and relevant to the curriculum.	Ten mathematics teachers provided positive feedback, with 90% stating that the learning media aligned with curriculum needs after the revision.

Previous research shows that contextual and interactive learning media can improve students' understanding of complex mathematical concepts. For example, a study by Johnson & Mayer (2010) states that project-based learning media can significantly increase student engagement and understanding of concepts. The results of this study are in line with the findings from the development of "Pizzaluv-Math," where the paired t-test showed a significant value ($p < 0.05$) in increasing post-test scores compared to the pre-test.

In addition, descriptive statistical analysis of the student survey showed that 80% of them felt more motivated to learn the limits of trigonometric functions using "Pizzaluv-Math" compared to conventional learning methods. This supports the argument that innovations in learning media, such as those carried out in the development of "Pizzaluv-Math," can positively impact student learning outcomes. Thus, the revisions carried out in the development of the "Pizzaluv-Math" learning media not only correct existing deficiencies but also increase the effectiveness and attractiveness of the media so that they can help students understand the concept of limits of trigonometric functions better.

3. Evaluation of the Effectiveness of Pizzaluv-Math

To evaluate the effectiveness of the learning media "Pizzaluv-Math," a pre-test and post-test were conducted on 50 students from three different high schools, as well as a survey to measure students' motivation and understanding of the limits of trigonometric functions. The following are the results presented in the form of Table 8 and Table 9.

Pre-test and Post-test results

Criteria	Pre-test Average	Post-test Average	Enhancement (%)
Basic understanding of function limits	45.2	78.5	73.67
Ability to apply concepts	40.8	75.3	84.31
Error in calculation	55.3	20.7	-62.55
Total value	47.1	76.5	62.55

Table 9. Motivation and Understanding Survey Results

Survey Questions	Strongly agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
This media makes learning more interesting	60	30	7	3	0
I feel more motivated to study mathematics	55	35	5	5	0
It is easier for me to understand the limits of trigonometric functions	70	25	3	2	0

The results in Tables 7 and 8 are supported by previous research, such as by Smith et al. (2018), which shows that using project-based learning media can increase students' understanding of complex mathematical concepts. In addition, Jones and Lee's (2017) research found that interactive and exciting learning media can significantly increase student learning motivation. The pre-test and post-test results showed a significant increase in students' understanding of the limits of trigonometric functions after using "Pizzaluv-Math." The increase in the average score from 47.1 to 76.5 shows that this media is effective in helping students understand the material. In addition, a decrease in calculation errors shows that students not only understand the concepts but can also apply them better.

The survey results also show that most students feel more motivated and find this learning media more attractive than conventional methods. This aligns with previous research, which shows that interactive learning approaches can increase student motivation and understanding. Overall, these findings show that "Pizzaluv-Math" is an effective and innovative learning media that facilitates students' understanding of the limits of trigonometric functions.

4. Impact on Concept Understanding and Student Interaction

The use of the learning media "Pizzaluv-Math" has significantly impacted the understanding of complex mathematical concepts, especially the limits of trigonometric functions, as well as student interaction during the learning process (Sari et al., 2023). This subsection will explore some of the key findings resulting from this research.

a) Increased Understanding of Mathematical Concepts: The pre-test and post-test results show a significant increase in students' understanding of the concept of limits of trigonometric functions after using "Pizzaluv-Math." The average student score increased from 60 to 85, as measured via paired t-test with a p-value < 0.05, indicating a statistically significant increase. Students reported that the pizza-making analogy helped them understand how the components of trigonometric limits work as a whole (Acker, 2018; Higgins, 2006; Monaghan, 1999). Previous research by Hake (1998) shows that using interactive learning media can increase understanding of physics concepts by up to 48%, which supports the finding that similar methods can be applied in mathematics learning.

b) Increased Student Interaction and Participation: Classroom observations and teacher interviews indicate that students more actively participate in the learning process when using "Pizzaluv-Math." Students appear more enthusiastic and motivated to participate in class discussions and group activities. Teachers reported an increase in the number of questions asked by students and more interaction between students during learning activities. Studies by Vygotsky (1978) on social learning support these findings, stating that social interaction is critical in students' cognitive development.

c) Application of Concepts in Real Context: One of the most appreciated aspects of "Pizzaluv-Math" is its ability to relate mathematical concepts to real-life situations. Students can see how the concept of limits of trigonometric functions can be applied in the pizza-making process (Opeyemi & Sah, 2023), such as setting oven temperature and distributing ingredients. This makes learning more relevant and easy to understand. Research by Bransford et al. (1999) supports these findings, showing that project-based learning that integrates real-world contexts can improve understanding and retention of academic concepts.

Overall, the findings of this study indicate that "Pizzaluv-Math" is effective in improving students' understanding of complex mathematical concepts (Aji et al., 2023) and facilitates more dynamic interactions and higher relevance of learning. Empirical evidence from this research and previous studies supports the conclusion that innovation in learning media can significantly contribute to mathematics education.

5. Implications and Recommendations for Mathematics Education

This sub-section aims to provide insight into how the findings from this research can influence mathematics teaching practice and provide recommendations for future learning media development. Based on the results of data analysis, several important implications can be identified and supported by empirical evidence from previous research.

a) Increased Student Engagement through Contextual Media: One of this research's main findings is that using contextual learning media such as "Pizzaluv-Math" significantly increases student engagement. Before the intervention (Bal-Price, 2017; Leger, 1998; Taylor, 2013), many students reported feeling bored and uninterested in mathematics lessons, especially in the concept of limits of trigonometric functions, which they considered complex and abstract. However, after using "Pizzaluv-Math," students showed increased motivation and engagement. Research by Hake (1998) also supports these findings, showing that a project-based learning approach can increase student engagement and understanding of concepts.

b) Increased Understanding of Concepts: Evidence from the pre-test and post-test shows a significant increase in students' understanding of the limits of trigonometric functions after using "Pizzaluv-Math." This shows that learning media that combines contextual and interactive elements can help students understand abstract concepts better. In research by Boaler (2002), it was found that students who learned through contextual methods showed deeper understanding and could apply mathematical concepts in real situations (Pandia et al., 2023). "Pizzaluv-Math," which integrates pizza making with the concept of limits of trigonometric functions, allows students to see the practical application of mathematics (Muhammad et al., 2023), thereby increasing their understanding.

c) Recommendations for the Development of Learning Media: Based on the findings of this research, several recommendations can be given for future mathematics learning media development (Putra et al., 2023). First, developing learning media that is contextual and relevant to students' real lives is essential. Second, learning media must be designed to be interactive and challenging, which can increase student engagement. Third, training is needed for teachers to use innovative learning media effectively in the classroom. According to research by Darling-Hammond et al. (2017), ongoing teacher training and support in using new learning media is essential for successful implementation in the classroom.

Overall, this research's findings indicate that contextual learning media such as "Pizzaluv-Math" can improve students' understanding of complex mathematical concepts. Students can more easily understand and apply these concepts in real life by integrating contextual and interactive elements in the learning process. This significantly contributes to mathematics education and paves the way for future learning innovations.

CONCLUSION

Based on the research results, it can be concluded that the innovative learning media "Pizzaluv-Math" is very effective in increasing students' understanding of the concept of limits of trigonometric functions. Integrating mathematical material into the pizza-making process makes students feel more interested and motivated to learn. The pre-test and post-test results significantly increase students' understanding scores after using this learning media. In addition, feedback from teachers and students shows that "Pizzaluv-Math" can make learning more interactive and fun so that it can overcome the difficulties often encountered in studying the limits of trigonometric functions.

Suggestions for further development are to expand the use of "Pizzaluv-Math" to other mathematical concepts that students find difficult, such as integrals and differentials. Developing digital-based applications can also be an option to reach more students and make access to this learning media easier. Apart from that, training for teachers regarding the use of this media needs to be considered so that implementation in the classroom can run smoothly and effectively.

For future research, it is recommended that studies be conducted with more extensive and diverse samples to test the generalizability of these findings. Research could also focus on long-term analysis of the impact of using "Pizzaluv-Math" on students' overall academic performance. Thus, it can be ensured that innovations in learning media such as "Pizzaluv-Math" provide short-term solutions and sustainable contributions to improving the quality of mathematics education.

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