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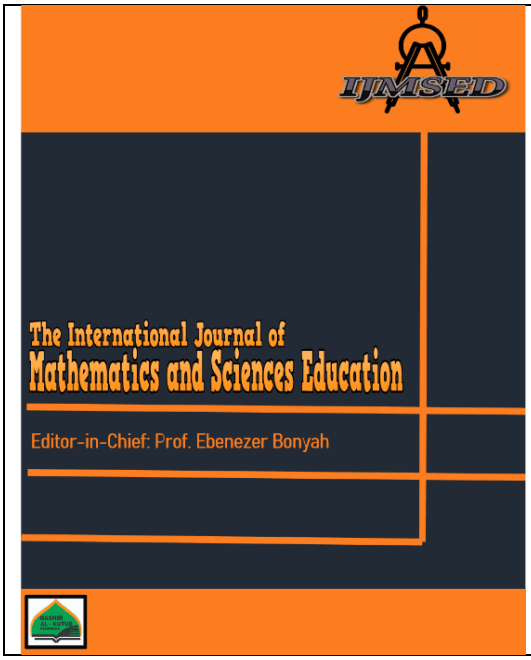

Plaque number board: visualizing the essence of exponents through simple proofs

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Plaque number board: visualizing the essence of exponents through simple proofs

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Abstract
The exponential power rule was one of the materials studied at the high school level. Students tended to memorize it rather than understand it. This caused students to have difficulty in applying the concept of exponents when working on non-routine questions. The ability to prove the properties of exponents in a simple way was needed to improve students' understanding, so a manipulative medium for the exponent power property called PLAKAT was created. This research aimed to examine the application of learning using the manipulative medium for the exponent power property known as PLAKAT. The research method used was qualitative with a case study approach. The instruments used to collect data included the manipulative media, video recording equipment, and observation notes. The subjects involved were practical students and audience students. The data collected consisted of video recordings and notes. The data were analyzed using interactive methods. The results of the research showed that this medium was useful for increasing students' understanding of the exponent power property. However, PLAKAT had a weakness: it did not have a rope, so it could not be hung, making its use less practical. This shortcoming served as a suggestion for teachers and students who intended to use this medium to prepare a more complete version to support smoother learning.

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1. Introduction

Mathematics students are expected to be able to carry out proofs of certain theorems (Iannone & Thoma, 2024). However, proof activities are still considered difficult for many mathematics students due to their lack of exposure to such tasks during their school years (Clements, 2000). Mathematical proof requires a strong foundation in mathematical experience, particularly in solving non-routine problems (Siregar, 2016). High school students are typically accustomed to receiving ready-made concepts without having to prove them, and they rarely encounter problems that require combining multiple concepts (Stadermann n& Goedhart, 2020). This makes proof activities quite challenging, especially considering that the learning of exponents at school is often limited to memorization. Memorization is a commonly used method for learning exponential concepts. Students are usually trained to memorize the laws of exponents without understanding the underlying proofs (Pinahayu, 2015). While memorization is fast and seemingly effective, it has weaknesses—memorized information is easily forgotten, and it does little to sharpen critical thinking and problem-solving skills.

The "PLAKAT" (Plaque Number Board for Exponents) instructional media serves as a solution to the overreliance on memorization in learning exponents. This tool is used to demonstrate simple proofs of five exponent rules commonly taught in secondary schools. One limitation of the PLAKAT media is that it is best suited for simple problems. Students are required to manipulate numbers

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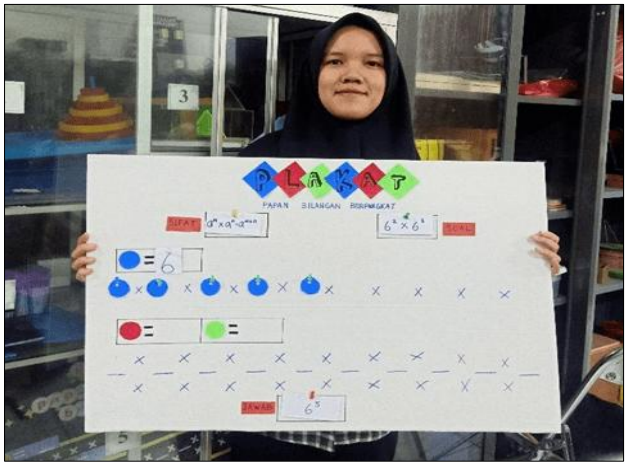
effectively when using the board, and they must already have a solid understanding of basic operations such as addition, subtraction, multiplication, and division.

The author hopes that exponent material will not merely be memorized by students but also understood in terms of how exponent rules actually work. Understanding the properties of exponents is crucial to prevent conceptual errors (Pujilestari, 2018). The Plaque Number Board helps students overcome difficulties in manipulating exponential numbers. When students understand how the laws of exponents operate, their ability to solve exponential problems will improve. With a strong conceptual grasp of exponents, students are expected to be able to solve both simple and complex problems. The PLAKAT board is also expected to help students not only understand but also prove the properties of exponents.

Figure 1

The Manipulative Media: PLAKAT



The Exponent Number Board has several advantages. It is designed with bright and attractive colors, as color can be a key factor in capturing students' attention and is one of the important elements to consider when designing simple instructional tools (Pebrianti, 2019). PLAKAT is also user-friendly, allowing students to operate it independently without teacher assistance. The board simplifies number forms into colored circles, making the concept easier to grasp. Despite these strengths, the board has some limitations. It provides only limited space for exponent values and is intended mainly for solving basic problems. Since it is designed to build conceptual understanding rather than tackle complex problems, more advanced tasks must be broken down into simpler components before using the board. The physical design of the PLAKAT media can be seen in Figure 1.

This paper was written to discuss and share the benefits of the "Plaque Number Board for Exponents" as a learning tool. It was hoped that this study would contribute positively to the advancement of education in Indonesia, especially in the field of mathematics education. It was also expected to inspire teachers, pre-service teachers, and students to create learning experiences that prioritized reasoning over memorization. With stronger reasoning skills, students would be better equipped to think critically and solve problems, ensuring that the knowledge they gained was applicable and long-lasting. In addition, this paper was written to fulfill an assignment for the Mathematics Instructional Media course.

2. Method

2.1 Research Design

This study employed a qualitative approach with a case study design. This approach was chosen because the research aimed to gain an in-depth understanding of how the PLAKAT manipulative media was implemented in teaching the properties of exponents to mathematics education students. The researcher was directly involved in the teaching process as a facilitator, making participatory observation an appropriate method in this context. The research began with the researcher greeting the students and providing an introduction to the topic of exponents. Following this, the researcher introduced the instructional media called "PLAKAT" (Plaque Number Board for Exponents) and explained its purpose as a tool to help demonstrate the five fundamental rules of exponents.

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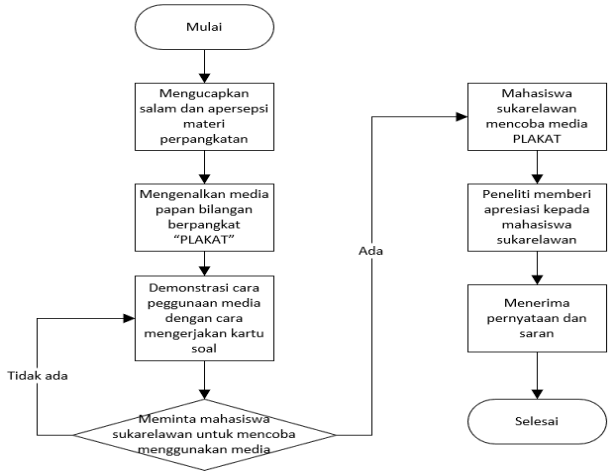
The next step involved a demonstration of how to use the PLAKAT board to solve exponent problems using task cards. After the demonstration, the researcher invited student volunteers to try using the media independently. If any students were willing, they were given the opportunity to operate the board in front of their peers. The researcher expressed appreciation for the participation and then collected feedback, including student comments, suggestions, and observations regarding the strengths and limitations of the PLAKAT media. The activity concluded with a summary and a reflection emphasizing the importance of understanding, rather than memorizing, the laws of exponents.

To support the research process, several data collection instruments were used, including participatory observation, video and photo documentation, field notes, and brief interviews or open-ended questionnaires. Observation was used to record student responses, engagement levels, and how effectively the media conveyed the mathematical concepts. Documentation captured visual evidence of the learning process, while field notes recorded significant moments and the researcher's reflections. Interviews and questionnaires provided deeper insights into the students' perceptions of the media's usefulness and limitations (Figure 2).

Figure 2
Flowchart



The data source consisted of students from Offering C, Class of 2022, enrolled in the Mathematics Instructional Media course who observed the explanation and demonstration of the media. Data were analyzed through student responses and questions posed during the demonstration of the PLAKAT manipulative media. The data could be reviewed through a recorded video of the practicum session. The tools used included the Exponent Number Board media and a mobile phone to record the learning activities. Table 1 below presents the tools and materials used in the development of the PLAKAT (Exponent Number Board) mathematics learning media.

Table 1
Tools and Materials for Creating the PLAKAT Media

No	Alat (Tools)	Bahan (Materials)
1	Scissors	Plastic Board
2	Hole Puncher	Asturo Paper
3	Ruler	Marker
4	Cutter	Push Pin
5	Bottle Cap	Double-sided Tape
6	Pencil	

How to Make the PLAKAT (Exponential Number Board) Media

The procedure for creating the PLAKAT media (Exponential Number Board) is described in several steps:

(1) Draw eleven circles each using a bottle cap as a guide on three colored asturo papers, each of a different color,

(2) Cut out the circles according to the pattern made,
(3) Punch holes in ten of the colored top circles using a paper punch,
(4) Draw 18 multiplication signs (crosses) and 10 division signs (slashes) using a marker, as illustrated in Figure 1,
(5) Stick one uncolored paper of each color using double-sided tape according to the design shown in Figure 1,
(6) Create a title using a marker or design it as creatively as possible,
(7) Prepare five cards representing the properties of exponents,
(8) Create one question card for each property,
(9) Create one answer card for each property,
(10) Create cards for numbers to be represented in each question,
(11) Punch a hole at the top of all cards,
(12) Store push pins, question cards, answer cards, and number cards in a container with separate compartments,
(13) The media is now ready to use.

2.2 Participants and samples

Case study research presents the perspectives of the subjects being studied (Assyakurrohim et al., 2023). The research subjects are practitioner students from cohort C, class of 2022, in the mathematics education department at Universitas Negeri Malang. The research procedure began with the selection of the topic—exponents. The researcher then searched for references and developed a suitable media concept for teaching exponents, which is the PLAKAT media. This was followed by the creation of the PLAKAT media and an instructional module to make practical activities more structured. The practical activity began with a greeting, followed by an introduction and motivation session where the objectives of the media were explained. The researcher then introduced the media and demonstrated how to use it by solving some exponent property question cards. Students were asked to try using the media themselves. The activity concluded with a Q&A session and feedback from students and the lecturer of the Mathematics Learning Media course.

2.3 Data Sources and Research Data

A data source is the subject from which data can be obtained (Arikunto, 2010). The data sources in this study are students from offering C of the mathematics department at Universitas Negeri Malang and the lecturer of the Mathematics Learning Media course. Sources were observed through responses, direct practice with the tool, questions asked during practice, and feedback afterward. The tools used include the PLAKAT manipulative media, a mobile phone as a timer, and a mobile phone to record the learning activity. The object of the research is the Exponential Number Board media, which serves to facilitate students' understanding of exponentiation. The research data includes video recordings of the learning activity using the media and notes from the course lecturer.

2.4 Data Analysis

The data analysis technique is a strategy that outlines how the data and information collected during the study are processed to determine the results. The technique used is interactive data analysis, which consists of four components: data collection, data reduction, data presentation, and conclusion drawing (Darmawan & Yusuf, 2022).

3. Results and Discussion

3.1 Results

Results

The research activity was conducted offline at Building B24, Department of Mathematics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang. This study took place on September 20, 2023. The research activity lasted for fifteen minutes, with a detailed breakdown of the activities presented in Table 2.

Table 2
Breakdown of Research Activities

	Preliminary Activities	Minutes
1	The researcher greets the students	0.5
2	The researcher explains the topic to be studied	0.5
3	The researcher gives an introduction to the topic of exponents	1
4	The researcher introduces the PLAKAT media and explains its purpose	1
Main Activities		
1	The researcher explains how to use the PLAKAT media	2
2	The researcher demonstrates the use of PLAKAT	5
3	The researcher asks for a volunteer from the audience (Offering C) to try using PLAKAT	3.5
Closing		
1	The researcher receives questions from the audience and the course lecturer	1
2	The researcher receives feedback and suggestions from the course lecturer	0.5

The table titled "Activity Schedule" outlines a structured sequence of learning activities conducted using the manipulative media called PLAKAT. It is divided into three main sections: Preliminary Activities, Main Activities, and Closing. During the Preliminary Activities, the researcher began the session by greeting the students, introducing the topic to be studied, and providing an initial overview of the exponent material. This phase aimed to create a focused learning environment and activate students' prior knowledge before engaging them with a new instructional tool.

In the Main Activities section, the researcher provided a clear explanation of how the PLAKAT media works, followed by a live demonstration showing how to use the media to solve exponent problems. This demonstration served as a concrete example of how the laws of exponents could be visualized through the use of colored number boards. Afterward, the researcher invited a volunteer from the Offering C group to try using the media in front of the audience. This activity encouraged student participation and allowed for experiential learning, helping to reinforce the conceptual understanding of exponent properties through hands-on manipulation.

During the Closing section, the researcher opened the floor for questions from both students and the course lecturer. This segment provided an opportunity for clarification, reflection, and knowledge reinforcement. Finally, the lecturer offered feedback and suggestions regarding the use of PLAKAT, contributing to the improvement of the instructional media and its future implementation. Despite the brief duration of each activity, the schedule was carefully designed to integrate theoretical explanation with practical application, promoting a deeper conceptual grasp of exponents in an interactive and student-centered manner.

Practice Process

The practice session went smoothly. During the stage where the researcher demonstrated the use of the PLAKAT media, neither the student audience nor the lecturer asked any questions regarding its use. The researcher invited one of the student audience members, who was also a research subject, to solve one of the question cards. However, no one volunteered, so the researcher continued by providing another example of how to solve a question card. The researcher then offered the audience another opportunity to try using the PLAKAT media. The volunteering student was free to choose any question card to solve, as long as it hadn't been previously explained by the researcher. The students appeared to have no difficulty using the media and were able to use it smoothly. When time was up, some properties had yet to be discussed. The audience and the lecturer of the Mathematics Learning Media course requested the researcher to explain one more property, which resulted in an extension of the session. The lecturer gave no comments or feedback on the PLAKAT number board media. The researcher

closed the session with a farewell greeting and expressed gratitude to the student audience from Offering C and the lecturer of the Mathematics Learning Media course as the conclusion of the research activity.

The PLAKAT number board media can enhance students' understanding of exponents, as indicated by the positive response from the audience, the ability of the volunteer student to understand and use the media fluently, and the absence of comments regarding conceptual errors in the media.

3.2 Discussion

The research activity began on September 20, 2023, at the Mathematics Department building of Universitas Negeri Malang. The activity started with a greeting. The researcher observed how the audience responded to the greeting. The audience responded enthusiastically, indicating their excitement and readiness to receive the material. Student readiness to receive learning material is crucial. This aligns with Slameto (2003), who stated that readiness to learn influences students' learning outcomes. In the context of teachers and students, when students show enthusiasm—meaning they are ready to receive the teacher's instruction—they will be motivated to optimize their learning outcomes (Effendi, 2017). The same happened during this research activity: if students, as the audience, are enthusiastic about what the researcher presents, they will strive to understand and focus on the session. An apperception activity was also conducted to assess whether the audience already had foundational knowledge for the core learning activity. Apperception serves to bridge prior knowledge and new material (Saidah et al., 2021). The findings indicate that the Offering C students already understood the properties and operations of exponents, suggesting that the PLAKAT media was highly likely to be understood by them.

The researcher continued by explaining the purpose of using the PLAKAT (Exponent Number Board) media. After introducing the media, the next activity was a live demonstration by the researcher on how to use it. The demonstration involved the researcher selecting one of the property cards to be proven through a simple problem using the PLAKAT number board. The following is one example of property verification by solving a pre-prepared question card.

Step 1: Take the property card and the question card that corresponds to that property. For example, the property and the question are:

$$a^m \times a^n = a^{m+n} \text{.....(1)}$$

$$6^2 \times 6^3 = 6^5 \text{.....(2)}$$

Step 2: Represent the number 6 as a blue circle by attaching the number 6 to the blue box.
Step 3: Attach 2 blue circles in the multiplication section, which means 6^2.
Step 4: Attach 3 blue circles in the multiplication section, which means 6^3.
Step 5: Operate the blue circles in the multiplication operation to obtain the result of blue^5.
Step 6: Convert the blue color back into the number 6 to get the final result of 6^5.

The purpose of providing examples is to improve students' understanding of how to use the media. This is in line with the research conducted by Emmawita (2018), which showed that teaching methods involving numerous examples can improve student scores at SDN 026 Pulau Godang Kari. The researcher then invited the audience to ask questions about the Exponent Number Board media. Neither the students nor the lecturer of the Mathematics Learning Media course raised any questions, leading the researcher to conclude that the use of the PLAKAT media had been well understood by the audience. The researcher gave an example of how the PLAKAT media is used, as shown in Figure 3.

Figure 3
The researcher provides an example of solving a problem using the PLAKAT media

The researcher asked one of the audience members to try using the PLAKAT exponent number board to assess their understanding of the media. However, none of the students volunteered to help the researcher. This prompted the researcher to continue the demonstration by selecting one of the property cards and a problem to solve. The audience was hesitant to try using the exponent number board because they were not confident in their mastery of the media and lacked the confidence to come forward and demonstrate it in front of others. They were afraid of making mistakes in using the media. This aligns with the findings of Zulpani et al. (2023), which state that there is a positive correlation between self-confidence and students' level of mathematical understanding. The researcher then decided to take another card to further reinforce the students' understanding of the PLAKAT exponent number board.

The researcher once again asked for a volunteer from the audience to try using the PLAKAT board to prove and solve a problem about the properties of exponents. One student voluntarily came forward and successfully solved the question card smoothly. This indicated that the audience member had a proper understanding of how to use the PLAKAT math learning media. The process of the student trying out the media is shown in Figures 4 and 5.

Figure 4
A volunteer from the audience trying the PLAKAT media

Figure 5
A volunteer from the audience solving one exponent property proof

The volunteer successfully solved a question card using the PLAKAT exponent number board. The researcher gave appreciation in the form of applause and words of thanks to boost the volunteer's enthusiasm and self-confidence. Moreover, such motivation is expected to encourage other students to be brave enough to step forward or volunteer if asked to come to the front again. Confidence is very important because it influences students' understanding of mathematical concepts. This aligns with the findings of Zulpani et al. (2023), which suggest that confident students are more likely to strive to improve their mathematical skills. Therefore, giving appreciation in any form is important in educational settings.

At this point, the practice session had ended, and the allotted time was up. However, one student asked a question about the use of the bottom section of the media. The part in question is shown in Figure 6. The lecturer of the Mathematics Learning Media course allowed the session to continue so the researcher could explain the function of the bottom part of the PLAKAT exponent number board. The researcher is seen continuing the demonstration in Figure 7. The bottom part of the PLAKAT media is used for solving problems that require division operations. The researcher continued the practice session by selecting a question card related to exponent division. After solving the card using the PLAKAT exponent number board, there were no further questions from either the lecturer or the students of Offering C. Since all questions had been addressed, the research activity was concluded.

Figure 6
Part of the media that was asked about

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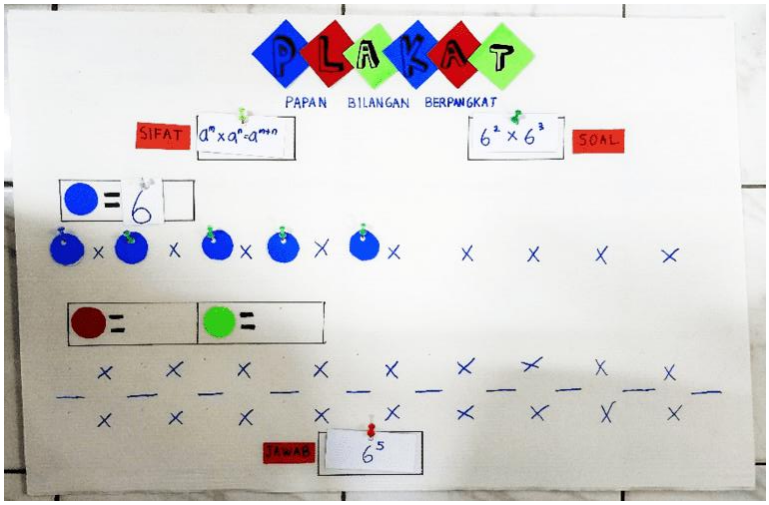
Figure 7
The researcher continues the demonstration

The conclusion of the research on the exponent number board media is to receive feedback and suggestions from the lecturer of the Mathematics Learning Media course. The researcher did not receive comments about the practical activity. The researcher also did not receive feedback about the exponent number board media. The lecturer did not provide any notes on the feedback form containing critiques and suggestions. This indicates that the practical use of the exponent number board media did not have any shortcomings. The manipulative exponent number board media, known as PLAKAT, has several advantages. The PLAKAT media has an attractive design. The colors used are bold and vibrant. Bright colors give a sense of enthusiasm, attractiveness, and lightness (Muhartati, et al., 2019). Although the colors are striking, the design of PLAKAT is relatively simple. The board is simply designed, making it easy to use. This board is designed for 11th-grade high school students, so the design and colors should be considered to attract students' attention and interest in the exponent number board media. The PLAKAT media can also be used by students independently without the help of a teacher, due to its simple operation. This media simplifies numbers into colorful circles, making it easier to understand. The design of the board can be seen in Figure 8.

Figure 8
Design of the PLAKAT Media



The exponent number board learning media PLAKAT also has some disadvantages. The media only provides space for a limited number of exponents. This media can only solve simple problems because it is designed to enhance understanding, not to solve complex problems. If this media is to be used for solving complex problems, the questions must be broken down into smaller, simpler parts. Additionally, the PLAKAT media does not have strings to hang the media, so assistance is needed to hold the media,

which can be seen in the lower right corner of Figures 3, 4, 5, and 7, or the media requires a stand to be used, making it less effective in its usage.

4. Conclusion

This study aimed to evaluate the effectiveness of the exponent number board media, PLAKAT, in supporting students' understanding of exponent properties. The findings confirm that PLAKAT serves as an effective, engaging, and user-friendly instructional tool that facilitates conceptual learning rather than rote memorization. By visually representing numerical relationships through colorful circles, PLAKAT aids students in manipulating numbers and mathematical formulas, thereby enhancing their mathematical thinking and problem-solving abilities related to exponents. Notably, students who used PLAKAT were able to independently solve exponent problems, demonstrating its potential for self-directed learning without requiring constant teacher assistance. The media's visual appeal and operational simplicity make it particularly accessible for young learners. Despite its pedagogical advantages, PLAKAT has certain limitations. It accommodates only a limited range of exponent values and is primarily suited for basic-level problems, aligning more with conceptual reinforcement than with the resolution of complex tasks. Additionally, its physical design lacks features for classroom practicality, such as a built-in stand or hanging mechanism, which may affect its usability in certain instructional contexts. Future research should explore the integration of PLAKAT with digital platforms to overcome physical limitations and expand its applicability to more advanced exponent problems. Moreover, studies involving larger and more diverse student populations could further validate its effectiveness across varied educational settings.

Author Contribution

Author 1: Conceptualization, Writing - Original Draft, Editing and Visualization;
Author 2: Writing - Review & Editing, Formal analysis, and Methodology;

Conflict of Interest

The authors declare no conflict of interest.

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