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The Influence of the Use of VR-Based Learning Media on Learning Outcomes and Learning Motivation of Students in Science Learning for Class IV SDN Sadeng 03

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ABSTRACT

This study aims to determine the effect of using Virtual Reality (VR) media on students' understanding and motivation to learn in learning Natural and Social Sciences (IPAS). The study was conducted with a quantitative approach using the ex post facto method, where researchers did not provide direct treatment, but analyzed data based on events that had occurred. The research subjects consisted of 16 students, with data collected through observation and questionnaires. The results of the analysis showed that 75% of students felt the benefits of using VR media in understanding IPAS material, while the other 25% showed doubts. In addition, the increase in IPAS scores that exceeded the Learning Objective Completion Criteria (KKTP) was also an indicator of the positive influence of VR media. In terms of learning motivation, 87.5% of students felt more motivated to use VR media, while the other 12.5% were doubtful. These findings indicate that VR media contributes to improving the quality of IPAS learning, both from the cognitive and affective aspects of students.
Keywords: Improved Learning Outcomes, Motivation to Learn, Virtual Reality,

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1. INTRODUCTION

The development of digital technology has changed the educational environment at various levels, including elementary schools. As part of learning in the 21st century, teachers not only need to provide materials, but also address them according to the characteristics of the digital-native generation, which is interesting and interactive. Students need to think proactively, creatively and critically about more dynamic training that is developing in a more dynamic direction. Learning is no longer focused on teachers *(teacher-centered)* , but is starting to shift to students *(student-centered)* . Students are directly involved in the learning process through exploration, collaboration, and the use of digital technology. This is a challenge and opportunity for the world of education, especially in the development of innovative learning media. The world of education has been greatly influenced by advances in modern technology, especially in terms of learning media, teaching techniques, and student perspectives. However, when older teachers face difficulties in adapting to contemporary learning trends, problems arise. Many of them still use traditional methods, such as lecture methods that take place continuously, using whiteboards, and assessing student learning outcomes through easily accessible learning modules, Student Worksheets (LKS). Memorization methods, or *mnemonics* , as well as learning approaches that center on passively gathering facts and information, referred to as the "banking model," are other conventional techniques often used by senior teachers.

Nowadays, students' needs are not only limited to delivering information verbally or visually; they also need media that can provide concrete, interesting, and relevant learning experiences to their world. *Virtual Reality -based learning media (VR)* is one type of developing media that can stimulate the senses, increase focus, and foster broad learning motivation (Handayani, 2022). *Virtual Reality (VR) technology* is one of the media innovations that is increasingly relevant to be applied in learning because it allows users to experience a virtual environment in real terms through certain devices, such as *virtual reality headsets* (Fitriya et al., 2022). In learning, VR can create a learning atmosphere as if someone is in a virtual object or shot.

The previous research that is relevant to the research conducted by the researcher is *the first research,* which conducted by Nurul Fitri Azizah, Marisa (2023). This study examines the use of *Virtual Reality* in science subjects in elementary schools which aims to improve student interaction in learning. This study has been proven to be able to improve and encourage student interaction and active participation in learning because students are given experiences in the form of VR displays that resemble real conditions, so that students are interested in actively participating in the learning process.

Secondly, a study conducted by Dharma, Sugihartini, and Arthana (2018). The objective of this research was to assess the learning results of children utilizing VR in comparison to those using Children's Worksheets (LKA) on the topic of vehicle recognition at TK Negeri Pembina Singaraja. The research indicated that utilizing VR greatly influenced student learning results at TK Negeri Pembina Singaraja (Dharma et al., 2018).

Third, research conducted by Rahmawati, Isjoni, and Yuliantoro (2024). To increase students' motivation at SMAN 2 Singingi to learn, this study created a VR video about Muara Takus Temple. The study showed that the developed learning media received a very decent assessment from material experts, media experts and students. In addition, students' learning motivation increased after using the learning media (Rahmawati et al., 2024).

By providing more concrete and in-depth visualization, VR-based media is considered to have the ability to improve the quality of the learning process. With VR, students can interact with their learning environment virtually. This improves conceptual understanding and increases active student participation (Aini et al., 2023). In science learning, there is a lot of abstract and difficult to understand material only with printed or verbal media. Therefore, VR technology can help overcome this problem because it can turn abstract material into a real and interesting learning experience (Majda et al., 2023). The use of virtual media not only affects student learning outcomes but also affects their motivation to learn. Students may be more enthusiastic and focused when participating in learning that involves new interactive technology, such as (Rosmah et al., 2023). Students have higher intrinsic motivation because they feel directly involved in the learning process rather than just receiving information passively. Motivation is a major component of learning success, especially at the elementary level (Nursyafitri et al., 2024).

The implementation of VR-based educational tools in elementary schools continues to encounter numerous obstacles. Certain issues include restricted devices, insufficient teacher guidance, and low digital literacy levels in elementary school settings. Nonetheless, Virtual Reality (VR) technology has demonstrated significant promise in enhancing student involvement in learning, aiding in the visualization of abstract ideas, and boosting students' motivation to learn. Research by Tsaaqib, Buchori, and Endahwuri (2023) showed that the use of VR is more effective than conventional learning in trigonometry material in high schools. Students in the experimental class achieved higher average learning scores than students in the control class. These findings suggest that further research is needed on how VR media functions in elementary school science learning. Thus, this technology can be used more widely and effectively in elementary education (Tsaaqib et al., 2022). The purpose of this study is to determine and analyze how the use of VR learning media impacts learning outcomes and student learning motivation in the subject of science in grade IV at SDN Sadeng 03. This study is expected to help develop learning methods that are more creative, fun, and have a positive impact on elementary school students.

2. RESEARCH METHOD

This study employs a quantitative method utilizing the *ex-post facto method* . According to Sugiyono (2015) in Wahdah & Malasari, (2022) He stated that ex-post facto research is utilized to investigate or analyze return factors or reasons stemming from the event being studied, in which the incident or occurrence has already occurred from the respondents' perspective. Ex post facto research aims to investigate events that have taken place and then examine the past to identify the factors that led to the occurrence of the incident the (Syahrizal & Jailani, 2023). Then study This aiming to determine the effect of VR-based learning media on learning outcomes and learning motivation of students in science learning of grade 4 SDN Sadeng 03. The ex-post facto research approach was selected as this study aims to investigate the impact of VR-based learning media on the learning outcomes and motivation of grade 4 students in science education at SDN Sadeng 03. The subjects of this research were fourth-grade students of SDN Sadeng 03 during the 2023/2024 school year, comprising a total of 16 students. The researcher employed a sampling method known as total sampling or saturated sampling from this population, which involves using every member of the population as samples (Amin et al., 2023). This technique is often used if the population is small with a sample size of less than 30 people, or for research that wants to make generalizations with a small or small error rate so that all members of the population are represented. then a sample of 16 grade 4 students of SDN Sadeng 03 in the 2023/2024 academic year was taken.

Data gathering methods were implemented through structured interviews, surveys, and documentation (learning notes and records of educational activities). Interviews with fourth-grade students were carried out through a questionnaire that included details regarding the utilization of VR-based educational media employed for fourth graders, particularly in science classes. Subsequently, a questionnaire was created to gather data on how VR-based learning media affects the learning outcomes and motivation of fourth-grade students in science education. The data was subsequently examined through descriptive statistical analysis. This research employs descriptive statistical data analysis methods intended to outline learning results and student motivation following the utilization of Virtual Reality (VR)-based educational tools. The data obtained through the questionnaire were analyzed by calculating the average value and percentage of each statement, then interpreted into categories such as very high, high, medium, low, or very low, according to the predetermined value range. In addition, data from the interview were analyzed qualitatively through the process of simplifying important information, presenting it in narrative form, and drawing conclusions to support the findings of the questionnaire data.

To confirm that the questionnaire accurately assesses the intended dimensions, a validity test is conducted in two phases: content validity and empirical validity. Content validity is achieved by gathering input from specialists, such as supervisors and class teachers, who assess whether each statement in the questionnaire is in accordance with the learning motivation indicators to be measured. After the questionnaire is declared feasible.

Empirical validity was analyzed using data obtained from all students using *the Pearson Product Moment correlation technique* , with the formula, $r_{xy} = \frac{n\sum xy-(\sum x)(\sum y)}{\sqrt{\{n\sum x^2-(\sum x)^2\}\{n\sum Y^2-(\sum Y)^2\}}}$.

Each statement in the questionnaire is compared to the overall score to see how well it represents what is being measured. A statement is deemed valid if its correlation coefficient exceeds the r table value at a specific significance level.

3. RESULTS AND DISCUSSION

A. Research Results

Based on the results of observations carried out by distributing questionnaires to respondents, data was found which was then analyzed and processed systematically by the researcher, thus obtaining research results which showed that

1. The use of VR-based learning media for class IV students at SDN Sadeng 03

Table 1. Results of the Questionnaire on the Use of VR-Based Learning Media for Grade IV Students at SDN Sadeng 03

Interval	Categories	Frequecy	%
106-125	Strongly agree	0	0
86-105	Agree	12	75
66-85	Nether agree	4	25
46-65	Disagree	0	0
25-45	Strongly disagree	0	0
	Totally	16	100

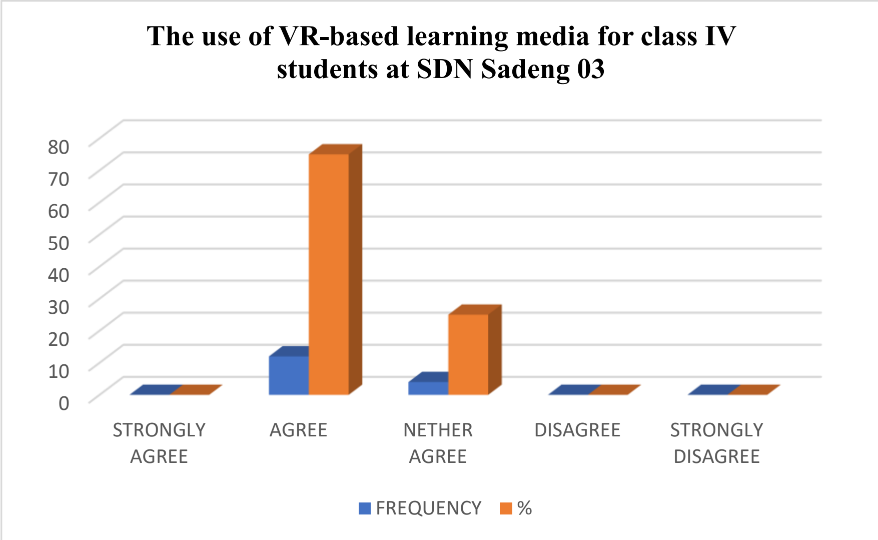

Fig 1. Use of VR-Based Learning Media for Class IV SDN Sadeng 03

2. Student motivation towards the use of VR-based learning media for class IV students at SDN Sadeng 03

Table 2. Results of the Motivation Questionnaire on the Use of VR-Based Learning Media for Grade IV Students at SDN Sadeng 03

Interval	Categories	Frequecy	%
106-125	Strongly agree	0	0
86-105	Agree	14	87,5
66-85	Nether agree	2	12,5
46-65	Disagree	0	0
25-45	Strongly disagree	0	0
	Totally	16	100

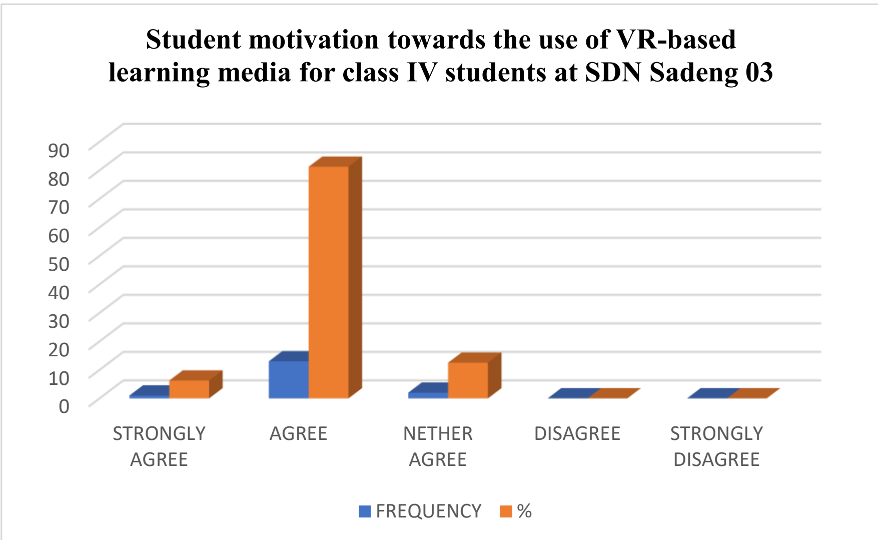

Fig 2. Student Motivation Towards the Use of VR-Based Learning Media in Class IV SDN Sadeng 03

B. Discussion

Learning outcomes using VR-based learning media in the subject of science for grade IV students at SDN Sadeng 03

Table 3. Learning Outcomes of Students in the Science Subject of Class IV SDN Sadeng 03

Number	Student Name	KKTP	Value
1	A	75	85
2	B	75	85
3	C	75	75
4	D	75	75
5	E	75	85
6	F	75	80
7	G	75	90
8	H	75	95
9	I	75	75
10	J	75	75
11	K	75	85
12	L	75	80
13	M	75	95
14	N	75	95
15	O	75	92
16	P	75	95

Learning using VR media is learning using sophisticated technology to visualize learning that seems abstract. This is also supported by the opinion of Eldiana, et al. (2022) who said that Virtual Reality Media is a media that can present real situations for its users, so that users can feel the atmosphere like the one in the media. So based on the results of the questionnaire, three results were obtained in the form of students feeling that the use of VR media in learning really helps them understand the material being studied. This is because Virtual Reality media is able to present real situations for students. So that virtual reality media can increase students' learning motivation. In addition, because its use only requires a smartphone, it adds practicality for its users, especially for use by elementary school students, most of whom are familiar with it in everyday life (Eldiana, et al.: 2022). Science learning tends to require media that visualizes the material being taught. so that the use of this VR media really helps students understand the contents of the material. this can be seen from 75% of the 16 students agreeing that there is an influence of the use of VR media in science learning and the other 25% are hesitant. The data is supported by the IPAS scores of students after using VR media, which shows that the assessment results exceed the KKTP.

VR media additionally impacted learning results. This is evident from the variations in the *pretest* and *posttest* outcomes conducted by Aini et al. 2023 which showed that utilizing VR media in elementary science education has been effective in enhancing student learning results. This is demonstrated by the outcomes of field experiments which indicate that the sig. The (2-tailed) value amounts to 0.096, which is greater than 0.05. Before impacting learning outcomes, there is typically an effect of heightened student motivation to learn, which fosters success in education. The success of student learning can be influenced by their level of motivation. Students with strong learning motivation generally achieve high results; on the other hand, if their learning motivation is weak, their academic success will also be diminished (Rahman Suharti, 2021)

From the observation data, 12.5% of students were hesitant that the use of VR media could motivate learning, but 87.5% of the total number of students were motivated to learn using VR media. This indicates that most students feel happy and interested in learning, thus motivating them to try to understand the material being taught. Overall, this can be interpreted that the use of VR media in science learning not only improves understanding of the material, but also contributes greatly to increasing learning motivation. Visual support and a more interactive learning experience make this media an effective alternative in creating a fun and meaningful learning atmosphere for students.

4. CONCLUSION

Virtual Reality (VR) tools in scientific education have demonstrated a beneficial effect on students' comprehension and enthusiasm for learning. Most students (75%) feel helped in understanding the material through the visualization provided by VR media, and their learning outcomes have increased beyond the KKTP. In addition, 87.5% of students admitted that they were more motivated to learn when using VR media, which shows that this technology is able to create a more interesting and interactive learning experience. In order for the use of VR media in learning to be more optimal, it is recommended that educators and schools continue to develop their abilities in using this technology through relevant training. Schools also need to provide adequate facilities and infrastructure and consider the balance between the use of technology and conventional learning approaches so that students do not depend entirely on digital media and remain physically and socially active in the learning process.

The use of VR in science learning still has great potential to be developed in the future. Future research can focus on combining VR with hands-on learning activities, so that students not only understand concepts visually, but are also practically skilled. It is also important to examine the long-term impact of VR on students' memory, critical thinking, and problem-solving skills. In addition, tailoring VR content to individual learning styles as well as the use of more affordable devices can encourage equitable access to this technology. These findings will be an important foundation in designing a more engaging, inclusive, and effective learning system.

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Knowledge Authority and Power Relations in Digital Non-Formal Education: A Foucaultian Perspective on Alternative Learning Spaces

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ABSTRACT

This study examined how digital non- -formal education platforms shaped knowledge authority and power relations within the Indonesian context. A qualitative case study of educational YouTube channels, national online courses, and global platforms was conducted through content observation, documentation, and critical discourse analysis grounded in Foucault's theory. The findings revealed a shift in knowledge legitimacy from academic authority to popularity metrics and algorithmic logic. Algorithms, gamification, and certification schemes act as disciplinary mechanisms that guide learning behavior while capturing user data. The learning subject was constructed as an independent and productive individual, yet simultaneously as a consumer and a data commodity. The study concluded that claims of digital educational inclusiveness remained partial, as access and digital literacy inequalities produced new forms of exclusion, and knowledge circulated fragmentarily outside the formal curriculum.

Keywords: Digital Non- -Formal Education, Knowledge Authority, Power Relations, Digital Platforms, Foucault Theory.

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1. INTRODUCTION

The wave of digitalization triggered by the COVID- -19 pandemic has radically transformed the education landscape. As schools and universities in more than 190 countries closed, more than one billion students shifted to distance learning, but at least 500 million of them failed to be reached by official online solutions (UNESCO, 2023). This massive shift has widened reliance on commercial platforms such as YouTube, Coursera, and social media, which are now seen as "alternative learning spaces" for the global public. In Indonesia, digital transformation strategies are a key development agenda, but the OECD continues to note geographic, gender, and age gaps in internet adoption, as well as widespread digital skills shortages across the education sector (OCED, 2024).

Optimism about digital inclusivity often masks structural issues. On the one hand, Indonesian-language "educational" YouTube channels reach millions of viewers, while paid short courses from Ruangguru to Skill Academy claim to "democratize knowledge." On the other hand, 2023 Susenas data shows that internet penetration in rural areas is only 35.9% compared to 64.1% in urban areas, and the provinces -with the lowest penetration are in eastern Indonesia (Jamilatuzzahro & Alaudin, 2024). The World Bank confirms that individuals in the highest income decile remain five times more likely to be connected than those in the lowest decile (World Bank, 2021). Infrastructure inequality has even prompted the government to partner with commercial satellite projects like Starlink to reach remote areas—an expensive solution that actually reinforces dependence on global technology corporations (Marketwatch, 2024).

Beneath the access issue lies a more subtle layer of concern: the authority of knowledge. Digital platforms operate as *gatekeepers of* truth through recommendation algorithms, *engagement metrics* , and micro-certification schemes. Research on the "platformization of education" shows that Big Tech, academic publishers, and the EdTech industry are restructuring knowledge infrastructure for the purposes of data extraction and financial value (Williamson, 2024). At the micro level, the *algorithmic literacy gap* has given rise to an algorithmic knowledge gap, where users with -higher socioeconomic status are better able to understand and manipulate algorithms and monetize YouTube content than those with less power (Cotter & Reisdorf, 2023). In other words, the digital divide has shifted beyond

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device ownership to the realm of algorithmic literacy, participation, and knowledge legitimacy (Van Dijk, 2020).

Academic literature on -digital non-formal education generally emphasizes pedagogical effectiveness, user experience design, or measurable learning outcomes. Few studies explicitly examine the power relations behind content curation, the logic of monetization, and the construction of learning subjects. Foucault's legacy has not been widely applied to understanding how algorithms act as disciplinary *apparatuses* that produce new "regimes of truth" in online educational spaces. The call for -critical sociological analysis is growing louder with the rise of paid online courses that position students as both consumers and data commodities.

This article departs from the Foucaultian power/knowledge framework (Foucault, 1977; 1980), which views knowledge and power as intertwined within institutional devices, discourses, and technologies. In the context of digital platforms, recommendation algorithms, instructional dashboards, and online certifications are understood as forms of *governmentality* —mechanisms for managing learning populations through performative norms and quantitative metrics. This approach allows for a three-layered reading: (i) the production and legitimation of knowledge; (ii) power relations in technological design; and (iii) the processes *of subjectivation* that shape the identities of "learners," "consumers," or "co-opted subjects."

Based on this framework, this study aims to: (1) identify how digital platforms produce and legitimize the authority of knowledge outside of formal education; (2) analyze the power relations that operate through algorithms, content curation, and platform design in directing learning experiences; and (3) reveal the process of constructing digital learning subjects who are positioned as active learners, consumers, or subjects co-opted by certain knowledge regimes. -These questions depart from the assumption that platforms are not merely neutral means, but fields of power contestation that produce new social differentiation.

The research's innovative value lies in integrating a Foucaultian perspective with contemporary digital inequality studies in Indonesia. First, this research links issues of access (*the first- -level digital divide*) with issues of knowledge legitimacy and algorithmic literacy (*the third- -level digital divide*), presenting a comprehensive map of inequality in -digital non-formal education. Second, this study produces analytical categories on how algorithms and platform designs, rather -than school institutions, discipline learning subjects. Third, the empirical findings are expected to provide policy input so that digital literacy initiatives and platform regulations are more sensitive to power-knowledge dynamics, not just technical infrastructure.

Thus, this article not only fills a gap in the literature on -digital non-formal education in Indonesia but also enriches the global debate on platforms, knowledge, and power in the post-digital era. Its spirit aligns with UNESCO's call for educational technology to be measured by the "right to meaningful connectivity" and not simply the distribution of devices (UNESCO, 2023), an ethical call that needs to be accompanied by a critical analysis of who benefits, who is repressed, and how learning is made possible.

LITERATURE REVIEW

Literature Review

Digitalization has expanded the scope of non-formal education by providing various forms of alternative learning spaces outside of formal institutions. Platforms like YouTube, Coursera, and various online course services open up access to knowledge previously only available within the context of a physical classroom (Selwyn, 2016). In Indonesia, the popularity of platforms like Ruangguru, Zenius, and Skill Academy reflects the phenomenon of "platformization of education," where the logic of the digital economy and information technology redefines the meaning of learning and the authority of teaching (Williamson, 2020; Nugroho, 2021).

However, this progress is not free from structural issues. The literature on *the digital divide* has identified three levels of inequality: physical access (first level), digital skills (second level), and the ability to utilize the internet for life improvement (third level) (van Dijk, 2020). In Indonesia, this gap is clearly visible: data from the 2023 Susenas (National Survey) shows that internet use for education in rural areas is much lower than in urban areas, with limited devices and internet costs being the main barriers (BPS, 2023). A study by Rakhmani & Siregar (2016) also noted that the digitalization of education often reaffirms social class inequalities, rather than eliminating them.

Previous studies have largely focused on the technical or pedagogical aspects of online education, such as the effectiveness of blended learning, digital curriculum design, or learning motivation (Alamary, 2019; Ningsih, 2022). However, very few studies have explicitly examined how knowledge authority is constructed in digital spaces, who holds epistemic power in determining truth, and how digital platforms reproduce or challenge existing social structures.

This paper fills this gap by presenting a critical reading based on Foucault's theory of how knowledge and power mutually shape digital learning spaces. By examining the content, design, and structure of digital non-formal education platforms, this article highlights not only the learning practices themselves but also the mechanisms of power that accompany them.

Theoretical Framework

Michel Foucault's concepts provide a critical framework for reading educational spaces as a field of power relations. In *Discipline and Punish* (1977) and *Power/Knowledge* (1980), Foucault states that there is no such thing as neutral knowledge; knowledge is the result of institutionalized power configurations conditioned by dominant discourses (Foucault, 1980).

The concept of *power/knowledge* is used in this research to analyze how knowledge authority is shaped through algorithms, platform design, and new authoritative figures such as educational content creators. In this space, epistemic power is no longer monopolized by formal institutions, but rather shifts to digital entities that shape narratives and authority through views, likes, or online certifications.

Governmentality is used to understand how power operates subtly through algorithms and design features (learning dashboards, notifications, digital reward systems). This governance over the learning subject occurs without direct coercion, but through incentives, performance measurements, and interface interactions that regulate how individuals understand themselves as learners (Foucault, 2008).

The concept *of subjectivation* is crucial for explaining how individuals are constructed as productive, independent, and responsive learners to platform demands. In digital learning spaces, students are expected to become "ideal subjects" who not only absorb knowledge but also demonstrate active engagement, self-branding, and sometimes even monetize their own learning content (Nugroho & Sumarno, 2020).

2. RESEARCH METHODS

This research uses a critical qualitative approach with an orientation towards the sociology of knowledge, aiming to unravel power relations in the formation of knowledge and learning subjects in the digital space. This approach was chosen because it allows for reading of social dynamics and discourses that are not directly visible, but operate subtly through digital technology. The method used is a qualitative case study of three types of platforms: *First,* educational YouTube (e.g., Kok Bisa, Zenius); *Second,* national online course platforms (Skill Academy, QuBisa); *Third,* global platforms (Coursera, EdX).

Data collection techniques were conducted through non-participatory observation of content displays, algorithms, and interactive features, course description documentation , video metadata, and assessment systems, and a Foucault-based critical discourse analysis to uncover the logic of power in learning structures and narratives. Data collection was conducted over three months, from January to March 2025. Non-participatory observation was conducted on 15 educational videos on the “Kok Bisa” and “Zenius” channels, 10 course modules on Skill Academy and QuBisa, and 5 Coursera programs. The data collected included content descriptions, visual displays, metadata (views, likes, comments), and platform features such as gamification and certification.

Data analysis was conducted through thematic analysis built from three main categories: the production of knowledge authority, technological power mechanisms, and the construction of learning subjects. The thematic analysis technique (Braun & Clarke, 2006), began with the *open coding stage* of the content narrative, then *axial coding* to group it into categories: knowledge authority, power mechanisms, and learning subjects. Validity was strengthened through cross-platform triangulation , as well as rereading of the data by the researcher to ensure consistency and depth of analysis. Triangulation was carried out by comparing patterns across three platforms and peer review validation by colleagues to maintain consistency of interpretation.

3. RESULTS AND DISCUSSION

Production of Knowledge Authority in Digital Non-Formal Education Platforms

A. Visual Dominance and Popularity as the New Authority

One of the key findings from observations of educational YouTube channels like "Kok Bisa" and "Zenius" is how popularity (number of subscribers, views, and engagement) becomes a primary indicator of knowledge authority. Compared to formal academic systems based on accreditation, degrees, or scientific publications, digital platforms create a new form of visibility-based legitimacy. Videos with engaging animation and fast delivery are more readily accepted as "valid knowledge" by viewers, even though they don't always have strong academic references (Foucault, 1980).

This aligns with Foucault's thesis on the regime of truth, which states that truth does not emerge solely from logical validity, but rather from its production and distribution through specific institutions and technologies. In this context, the YouTube platform acts as an algorithmic institution that validates knowledge based on technical performance.

B. The Role of Content Curators as "New Teachers"

Online courses like Skill Academy and Coursera demonstrate that content curators (content developers and tutors) now play a crucial role in authoritative knowledge. However, compared to traditional teachers who hold teaching licenses or are bound by national curricula, these curators tend to come from professional industries. They are positioned as practitioners who are "more relevant" than academics.

This phenomenon demonstrates a shift in epistemic power: from the educational bureaucracy to the digital private sector. Correspondingly, several narratives on the platform, such as "learning from successful mentors" or "mastering skills quickly," illustrate how a pragmatic orientation has become dominant in knowledge production (Rakhmani & Siregar, 2016).

Power Mechanisms in Algorithms and Platform Design

A. Algorithm as a Normalization Mechanism

Another important finding is how algorithms operate as mechanisms of power, determining what users see, learn, and ignore. On YouTube, algorithms recommend videos based on viewing history, trends, and interactions. This creates a highly personalized learning space, but it also blocks critical reflection on the material.

This mechanism demonstrates the practice of disciplinary power as described by Foucault (1977), where algorithms act like invisible supervisors that direct learning behavior without explicit coercion. Learning subjects are unaware that they are being directed to continue consuming a particular type of knowledge.

B. Gamification and Certification Schemes as Disciplinary Techniques

Platforms like Skill Academy and Ruangguru employ gamification systems (points, badges, progress bars) and certificates to entice learning. While effective in increasing participation, this strategy also creates performative pressure and anxiety to complete modules without truly understanding the content. This supports the concept of governmentality, where individuals are encouraged to self-regulate to meet standards set by the platform system.

Construction of Learning Subjects in Digital Space

A. Subjects as Independent and Productive Learners

Non-formal education platforms shape students as independent learners who are responsible for their own progress. Slogans like "learn anytime," "skills for the future," and "career starts here" demonstrate how learning is positioned as an individual project. This reinforces neoliberal logic in education, which obscures the role of the state and collectives in education provision.

B. Subjects as Consumers and Commodities

Another aspect of the construction of digital subjects is how students are also positioned as consumers of educational products. In Skill Academy, for example, users can purchase various classes based on promotions, ratings, and testimonials. In fact, user behavioral data is used to design subsequent promotions. Furthermore, students also become data commodities. Their interactions are recorded, analyzed, and used as the basis for commercial decisions by the platform. This is where power positions become complex: students are not only users but also objects of a knowledge system controlled by algorithms and market logic.

Social Implications: Pseudo-Inclusivity and Knowledge Fragmentation

While seemingly inclusive, digital non-formal education spaces create new forms of exclusion. Lower-class users with low digital literacy tend to access popular but shallow materials, while middle-class groups with premium access can take intensive courses and network globally (BPS, 2023).

Furthermore, the logic of algorithm-based curation leads to the fragmentation of knowledge. There is no unified curriculum structure, so users often access knowledge in a fragmented and unsystematic manner. This reinforces Foucault's critique that modern knowledge production is increasingly divorced from formal pedagogical functions and more closely resembles the consumption of scattered and fragmented information (Foucault, 1980).

Knowledge Authority in Digital Platforms

Digital platforms shape knowledge authority based on popularity and technological design, rather than academic validity. Algorithms and gamification features act as power mechanisms that discipline and regulate learning subjects. Learning subjects are constructed as independent learners, consumers, and data objects. The inclusiveness of digital education is illusory because it is still based on access, social class, and algorithmic literacy. Digital non-formal education demonstrates a shift from a pedagogical system to a fragmented model of knowledge consumption. By understanding these five findings, this paper suggests that digital education policy in Indonesia should not only focus on technology distribution but also pay attention to power structures, knowledge production, and the forms of learning subjects generated by platforms.

Discussion

The findings of this study confirm that power relations in digital education spaces are not only mediated by technology but also institutionalized through algorithmic structures and performative narratives. Within the *power/knowledge framework* , as proposed by Foucault (1980), algorithms and the logic of popular visuality shape new knowledge authorities, replacing conventional academic authority. This is evident in how educational YouTube channels are judged credible based on the number of views and engagement, rather than scientific validity. This process is intertwined with *governmentality,* where features such as certificates, progress bars, and notifications encourage individuals to self-regulate in a disciplined manner to continue learning and be productive (Foucault, 2008). Furthermore, the process *of subjectivation* occurs when digital learners are constructed as ideal subjects who are autonomous, competitive, and responsive to the demands of algorithms and the market (Nugroho, 2021). These findings align with Cotter and Reisdorf (2023), who highlight *algorithmic knowledge gaps* in educational platforms, and Van Dijk (2020), who suggests that the third-level digital divide now determines actual inequality. Williamson's (2020) and Rakhmani & Siregar's (2016) studies also emphasize that educational platformization creates a new power structure that aligns users as consumers and commodities in a data capitalism system.

These findings align with Nugroho's (2021) study, which shows that educational platformization in Indonesia reinforces market logic and popular visualizations as indicators of authority. Similar findings are found in India, where EdTech platforms like Byju's create "virtual teachers" based on motivational narratives and performative logic (Chattopadhyay, 2022). In Brazil, de Souza's (2023) study demonstrates how educational platforms collect learning behavior data to be used as advertising commodities. This comparison demonstrates that the tendency of platforms to act as spaces for the reproduction of power is a global phenomenon in Global South countries.

Table 4.1. Mapping of Power Mechanisms in Digital Platforms

Dimensions of Power	Practical Form on Platform	Foucault's Concept
Knowledge Authority	Popularity, engagement, mentor rating	Regime of truth
Disciplinary Mechanism	Recommendation algorithms, gamification, certificates	Disciplinary power
Self-Government	Progress bar, self-study notification	Governmentality
Subjectivation	Self branding, content monetization	Subjectivation
Digital Exclusion	Access gap, algorithmic literacy	Biopolitics, exclusion

Mapping power in digital platforms reveals five main dimensions: (1) authority based on technical performance; (2) normalization through algorithms and popular visualizations; (3) self-governance mechanisms via gamification features; (4) subjectivation in the form of the neoliberal ideal student; and (5) reproduction of exclusion through access structures and algorithms. These five dimensions work simultaneously to form indirect but highly determinant power relations.

4. CONCLUSION

This research has successfully achieved the objectives as formulated in the Introduction, namely to analyze how digital non-formal education platforms such as YouTube, Skill Academy, and Coursera shape knowledge authority and construct learning subjects within a framework of power relations. The findings presented in the Results and Discussion chapters indicate that this phenomenon can be explained not only through the dynamics of technology and accessibility, but also through a critical analysis of the mechanisms of power that operate covertly through algorithms, content curation, and platform design structures.

Some of the main conclusions that can be drawn from this research are as follows:

A. Digital platforms are shaping new knowledge authorities, shifting from traditional academic authority towards legitimacy based on popularity, visuality, and algorithmic logic.
B. Algorithms and other interactive features function as mechanisms of power that discipline the learning subject, indirectly determining the type of knowledge accessed, the rhythm of learning, and the form of engagement expected.
C. Learning subjects in digital space are constructed as independent, productive individuals who are responsible for their own progress, but also function as consumers and data objects in the logic of the digital economy.
D. Claims of inclusivity in digital education are partial and problematic, as inequalities in access and digital literacy create deeper social class divisions in terms of knowledge acquisition.
E. The knowledge produced and consumed in digital educational spaces tends to be fragmented, not bound by a structural curriculum, and more like a process of information consumption than a systematic formal education.

From the results of this study, there are a number of theoretical and practical implications that can be taken:

A. Theoretical Implications: This research extends the application of Foucault's theory to the context of contemporary digital education, specifically in mapping how power/knowledge, governmentality, and subjectivation operate in technology-based informal spaces. This suggests that power relations in education no longer operate directly, but through seemingly neutral technological infrastructures.
B. Practical Implications: These findings are important for policymakers, online learning platform developers, and educators to be more critical of the impact of algorithms, content curation, and learning design models on the formation of learning subjects and the dissemination of knowledge. Intervention strategies based on digital justice and critical literacy for learners are needed.

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Analysis of Classroom Management Skills of Prospective Vocational Teachers during Teaching Practice in DKI Jakarta

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ABSTRACT

This study examined the classroom management skills of prospective vocational teachers in the Building Construction Expretise Program during teaching practice in DKI Jakarta. Participants were 17 prospective teachers and 286 students, selected through purposive sampling. The study used a mixed-methods sequential explanatory design, combining quantitative data from a Likert-scale questionnaire and qualitative data from classroom observations. The prospective vocational teachers showed strong skills in creating a positive classroom environment (76.2%) and preventing problems (72.0%). However, they had dificulties in managing existing problems (53.4%) and in building effective classroom systems (46.0%). Weak areas included enthusiasm for teaching, giving praise and criticism, giving rewards and punishments, coaching, managing mobile phone, classroom design, motivating students, and building relationships. These findings indicate that prospective vocational teachers need more training and examples to improve their classroom management skills.

Keywords: Classroom Management Skills, Prospective Vocational Teachers, Teaching Skill Practice

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1. INTRODUCTION

Education is a vital factor in the development and progress of a nation. It is a continuous process of shaping learners' character through various approaches to ensure they acquire the knowledge, understanding, and behavior aligned with national values. High-quality education plays a crucial role in advancing a country's future (Mu'minah, 2020). Therefore, every nation must consistently strive to improve its education quality, encompassing both general and vocational education.

Vocational education holds particularly importance because it equips students with specialized skills that match industry needs, enabling them to enter the workforce more quickly. Data from the OECD (2020) show that graduates of vocational programs in several countries often have higher employment rates than graduates from general education streams. To maintain and improve the quality of vocational education, prospective vocational teachers must master a set of basic teaching skills.

Basic teaching skills are essential for prospective vocational teachers to conduct learning activities efficiently, effectively, and professionally, ensuring that learning objectives are achieved optimally (Salsabila et al., 2023). Irawati (2020) classifies these skills into eight categories: opening and closing lessons, explaining, questioning, guiding small group discussions, classroom management, reinforcement, varying stimuli, and teaching individuals and small groups. Among these, classroom management is often one of the most greatest challenge (J. M. Cooper, 2014). Nasution & S (2022) further emphasize that the role of a vocational teacher extends beyond delivering academic content, it also include creating and maintaining a learning environment that fosters student engagement and achievement.

A relevant example is provided in a study by Laela (2025), titled "*Analysis of Classroom Management Skills Implementation by Prospective Vocational Teacher during Teaching Practice in Vocational Schools*." Conducted among students of the Building Engineering Education (BEE) Program at Universitas Negeri Jakarta (UNJ), the research identified several external factors hindering classroom management, including insufficient facilities (23%), student behavior issues (21%), individual difficulties (20%), administrative problems (18%), and teacher-related behavior (17%). The findings highlight that inadequate facilites and learning resources can significantly disrupt the teaching and learning process.

While Laela's study focused on external obstacles to classroom management, the present study examines internal competencies-specifically, the skills of prospective vocational teachers in managing classrooms. This research evauates their mastery using three key indicator: principle, concept, and aspects of classroom management. The objective is to measure proficiency, identify areas of weakness, and provide insights for improving academic instruction and field training.

Classroom management is a core teaching skills essential for ensuring that learning proceeds effectively and efficiently (Fauziah & Guslinda, 2019). It involves six principles: warmth and enthusiasm, challenge, variety, flexibility, emphasis on positive aspects, and discipline reinforcement. It also includes five concepts: classroom design, rules and routines, relationships, engagement and motivation, and discipline (Halimah, 2017). Furthermore, encompasses two major aspects: preventive and repressive (Mulyasa, 2015). However, few studies have comprehensively analyzed classroom management based on these three indicators.

Mastery of classroom management cannot be achieved solely through theoretical knowledge. It requires consistent training and real-world practice. The Teaching Skills Practice (TSP) program serves this purpose by providing prospective vocational teachers in the construction field with oppurtunities to apply classroom management theories in authentic classroom settings, thereby strengthening both their pedagogical and technical competencies (Yarmi, 2019).

2. RESEARCH AND METHOD

This study employed a mixed methods sequential explanatory design, in which quantitative data were collected and analyzed first, followed by qualitative data collection and analysis. The quantitative phase involved the use of structured questionnarie to measure classroom management skills from two perspectives: the perception of prospective vocational teachers and the perception of secondary school students. The instrument used a five-point Likert scale ranging from "Never" (1) to "Very Often" (5), with intermediate points representing "Rarely" (2), "Sometimes" (3), and "Often" (4). Items included both positively and negatively worded statements.

The questionnaire was adapted from established classroom management frameworks (Nuraliyah, 2020; Widyarani, 2011; Widiyono, 2020; Oprianti, 2023; Fauziah & Guslinda, 2019; Panjaitan, 2024; Nurmalasari, 2022). Instrument validity and reliability testing were conducted using IBM SPSS 26.00 with a trial involving 14 prospective vocational teachers from the Building Engineering Education (BEE) Program and 17 students who had been taught by these prospective teachers during semester 121. The results confirmed that the instrument met the required validity and reliability standards.

The qualitative phase employed a classroom observation instrument to complement and explain the quantitative findings. The observation checklist was developed based on the gaps identified from the questionnaire data. Observations focused on the same indicators used in the quantitative instrument (principles, concepts, and aspects of classroom management). Prospective vocational teachers were observed while teaching in actual classroom settings. Field notes were compiled, and data were coded thematically. An initial coding framework was created deductively from the research framework, then refined inductively as additional themes emerged.

The sampling technique used was purposive sampling, targeting participants who met the research criteria. The study sample comprised 17 prospective vocational teachers from the BEE Program at Universitas Negeri Jakarta (UNJ) undergoing the Teaching Skills Practice (TSP) program in semester 122, along with 286 students they taught. The vocational schools involved were SMKN 1 Jakarta, SMKN 26 Jakarta, and SMKN 52 Jakarta.

3. RESULTS AND DISCUSSION

A. Principles of Classroom Management Skills

Analysis of questionnaire responses and classroom observations showed that the highest levels of mastery among prospective vocational teachers were in creating challenging tasks (94.7%), arriving on time (85.3%), and speaking clearly and audibly (77.6%). Prospective teachers also demonstrated the ability to adapt teaching methods to students' characteristics (70.6%). These strengths align with previous findings that challenging yet relevant tasks can enhance student engagement and reduce misbehavior (Widiyono, 2020), while punctuality fosters discipline and allows prospective teachers to prepare learning materials effectively (Fatmawati et al., 2023). However, two areas showed weaker performance. First, enthusiasm at the start of lessons was rated lower (64.7%), suggesting that some prospective teachers lacked the energy or motivational presence needed to set a positive tone. Socio-emotional readiness, both from prospective teachers and students, is crucial for sustaining an enjoyable and effective learning atmosphere (Aliyyah & Djuanda, 2016). Second, the ability to provide varied and specific praise was limited (64.0%). Observations revealed that praise was often restricted to applause or generic affirmations such as "good" or "absolutely correct," rather than personalized feedback. Research shows that effective praise such as mentioning the student's name, highlighting specific behaviors, and using both verbal and non-verbal cues can significantly boost motivation and classroom climate (Rasana, 2009). Overall, the average mastery across all six principle indicators was 76.2%, indicating that while core competencies in classroom management principles were generally strong, targeted improvement is needed in enthusiasm-building strategies and praise variation.

B. Concept of Classroom Management Skills

Analysis of questionnaire responses and classroom observations showed that the highest levels of mastery among prospective vocational teachers were in maintaining classroom order and discipline (82.5%). This ability to control classroom behavior is essential for creating a structured learning environment and instilling good habits in students (Harahap, 2016). In contrast, four other concept indicators showed weaker mastery. The lowest was in implementing rules for mobile phone use during lessons (5.9%). Observations confirmed that most prospective teachers did not consistently remind students to switch off their devices, and when rules were given, enforcement was inconsistent. Effective classroom management requires clear, consistently applied policies on device usage to minimize distractions (Thomas et al., 2018). Classroom design and seating arrangement also scored low (35.3%). Many prospective teachers simply instructed students to sit with their assigned groups, while only a few used intentional layouts such as the U-shape arrangement that can enhance interaction. This finding supports previous research showing that strategic seating arrangements can improve motivation and learning outcomes (Rohmanurmeta & Farozin, 2016). Motivating students at the start or end of lessons was another weak point (47.0%). While some prospective teachers incorporated ice-breaking activities, others began instruction without any motivational engagement. Such practices overlook the role of motivational strategies in boosting student enthusiasm and participation (Riadin & Estimurti, 2022). Finally, building strong relationships with students was not consistently achieved (59.1%). A lack of rapport may hinder trust and student willingness to participate actively. Positive prospective teacher and student relationships have been shown to increase engagement and foster a pleasant learning atmosphere (Iswardhany & Rahayu, 2020). The average mastery across all five concept indicators was only 46.0%, with discipline maintenance as the only consistently strong area. This suggests the need for targeted training in classroom layout strategies, motivational techniques, relationship-building, and enforcing rules particularly for mobile phone use.

C. Preventive Aspects of Classroom Management Skills

Analysis of questionnaire responses and classroom observations showed that the highest levels of mastery among prospective vocational teachers was the ability to treat all students fairly (88.1%). Observations confirmed that most prospective vocational teachers avoided favoritism and provided equal opportunities, an approach that supports an inclusive and supportive learning climate (Pangaribuan et al., 2025). Other strong areas included giving students time to prepare before lessons began (84.3%), assisting students who had difficulty with tasks (83.3%), and providing clear and understandable instructions (82.5%). These practices are critical for ensuring students are ready to engage, feel supported in their learning, and understand expectations before working independently (Rosenshine, 2012). However, two areas showed significant weaknesses. The first was a lack of assertiveness in giving warnings to disruptive students (58.8%). Observations revealed that prospective teachers often overlooked behaviors such as phone use or unrelated work during class. Firm and consistent intervention is necessary to maintain a conducive learning environment (Emmer et al., 1980). The second was limited use of rewards for well behaved students (35.0%). Prospective teachers rarely offered recognition, whether verbal, symbolic, or tangible, to reinforce positive behavior. Effective reward strategies such as specific praise, small privileges, or symbolic tokens—can enhance motivation and encourage a positive classroom atmosphere (Nur Arsyah et al., 2024). The average mastery across the six preventive indicators was 72.0%. While fairness, preparation time, task assistance, and clear instructions were strong, prospective vocational teachers need further training in assertive classroom discipline and the strategic use of rewards to strengthen preventive management practices.

D. Repressive Aspects of Classroom Management Skills

Analysis of questionnaire responses and classroom observations showed that the highest levels of mastery among prospective vocational teachers was in encouraging active participation during group discussions (73.4%). Observations showed that prospective teachers moved around the classroom, monitored group work, and encouraged contributions although in some cases, only certain groups were actively engaged. Ensuring that all members participate equally is essential for maximizing the benefits of collaborative learning (Johnson et al., 2014). In contrast, two areas showed notably low mastery. The first was implementing sanctions for disruptive behavior (26.4%). Prospective teachers often relied on verbal warnings or threats, such as confiscating mobile phones, without consistently following through. This inconsistency reduces the effectiveness of rules and undermines authority. Training on case-based strategies and simulation-based practice can help prospective teachers develop a firm yet fair approach to discipline (Marzano & Marzano, 2003). The second weakness was addressing problematic student behavior (60.3%). Many prospective teachers did not attempt behavior modification, focusing instead on content delivery. This suggests a need for capacity building in corrective strategies, including positive reinforcement, restorative approaches, and structured consequences (Ananda, 2019). Without these skills, disruptive behaviors can persist and negatively affect the learning environment. Overall, the average mastery across the three repressive indicators was 53.4%. While prospective vocational teachers showed strength in promoting group participation, they require further training in consistent disciplinary action and behavior modification techniques to effectively address ongoing classroom issues.

4. CONCLUSION

Based on the research findings and discussion, prospective vocational teachers demonstrated strong mastery in the principle and preventive aspects of classroom management during the Teaching Skills Practicum (TSP). However, competencies in the conceptual and repressive aspects require further reinforcement. In the principle aspect, improvement is needed in maintaining teaching enthusiasm and delivering effective, varied praise. In the concept aspect, areas for development include enforcing rules on mobile phone use, arranging classroom seating strategically, providing motivational activities, and fostering positive prospective teacher and student relationships. Within the preventive aspect, skills such as giving timely and assertive reprimands and rewarding positive behavior remain underdeveloped. For the repressive aspect, disciplining disruptive students and guiding those with problematic behavior require additional focus. These findings highlight that while prospective teachers are generally capable of establishing a conducive classroom environment and preventing issues, they face challenges in implementing structured systems and addressing ongoing behavioral problems. Addressing these gaps is critical for ensuring that vocational graduates are fully prepared for the complex realities of classroom teaching.

Prospective teacher training institutions should integrate practical modules on classroom management that emphasize both preventive and repressive strategies, provide simulation-based training and microteaching sessions focusing on behavior modification, praise variation, motivational techniques, and consistent rule enforcement, incorporate case-based learning to help prospective teachers practice handling diverse classroom scenarios, and ensure mentorship and feedback loops during TSP, enabling prospective teachers to reflect on and refine their classroom management approaches. By implementing these measures, prospective teachers can better prepare future to not only maintain order but also foster an engaging, supportive, and well-managed learning environment.

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The Effect of the Use of the Jarimatika Method on the Learning Outcomes of Multiplication of Grade III Elementary School Students

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ABSTRACT

Multiplication is one of the challenges that is quite difficult for elementary school students because it requires the ability to understand concepts and memorize. Students have been introduced to the concept of basic multiplication in class III. But in practice, children still have trouble remembering simple multiplications. The purpose of this study is to find out whether the multiplication learning achievement of third grade elementary school students is influenced by the Jarimatika approach. This study uses a quantitative approach with a Posttest-only control design and a quasi-experimental design. Two groups participated in this study: the experimental group, which will apply the Jarimatika method to third graders at SDN Dawu 2, and the control group, which will not apply the Jarimatika method to third grade students at SDN Wonokerto 1. Multiple-choice posttest is the data collection method used in this study. Test instrument testing, prerequisite testing, and hypothesis testing are the data analysis methods used. The calculation of the Independent Sample t-test yielded a significance value of < 0.05, or 0.002, based on the data. Furthermore, $t_{count} > t_{table}$ was also found, which was 3.465 > 2.048, indicating that H_0 was rejected and H1 was accepted. Thus, it can be said that the learning outcomes of third-grade children are influenced by the Jarimatika technique.

Keywords: Jarimatika Method, Learning Outcomes, Multiplication

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1. INTRODUCTION

Learning can be interpreted as a link between students and their desired goals/ideals. During learning activities, students will be assisted by teachers. Collaborative skills between instructors and students are essential for the success of any educational endeavor. One strategy to help students achieve their learning goals is to provide the right learning tools (Wijayanti & Rahmawati, 2019). By providing direction for the implementation of learning activities, learning strategies ensure efficient and successful learning (Noza & Wandira, 2024).

Teachers use a variety of learning methods to ensure students fully understand the subject matter and achieve learning objectives (Bunyamin, 2021). Choosing the right learning techniques is very important because it affects the achievement of learning objectives. Learning activities are completed when the learning objectives are achieved. Utilizing learning strategies improves the educational experience for educators and students. With the right teaching methods, students will have an easier time understanding the concepts taught in mathematics and other subjects that rely on numerical formulas. Mathematics is one of the less popular subjects because it requires the use of computing to solve problems with complex combinations of numbers (Authar et al., 2022). Students need to master the four basic arithmetic operations of addition, subtraction, multiplication, and division during elementary school as these operations will be used throughout their academic career. One of the calculation operations that is quite difficult for students is the multiplication calculation operation.

Multiplication is one of the challenges that is quite difficult for elementary school students because it requires the ability to understand concepts and memorize. Students can memorize if they have a basic understanding of the concept of multiplication (Nursofia Zain et al., 2022). Multiplication itself is a development of a continuous repeating addition calculation operation or can also be known as a derivative of the addition calculation operation. Multiplication in basic calculation operations will continue to be used until the next school level (Hamdani et al., 2024). Basic multiplication such as multiplication of 1 – 10 is very important to master because the more the school level increases, the more difficult and complicated the multiplication operation becomes. The basic multiplication

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calculation operation is one of the bases for the next material such as flat construction, space construction, factor, multiple, and so on. If students have not fully mastered the basic multiplication calculation operation, then students will have difficulties in the next material. In addition to being important in the learning material, basic multiplication will also be used in daily life because many activities require multiplication calculations (Nursofia Zain et al., 2022).

Many elementary school students have difficulty mastering basic multiplication operations. This is because students have not fully understood the concept of multiplication itself so that students experience confusion when calculating it (Rahayu et al., 2022). In addition, it can also be because students are still calculating manually, namely by counting one by one using their fingers. It is still effective for use in lower multiplications such as multiplication of 1 – 5, but for upper multiplication such as multiplication of 6 – 10 is not effective. If these difficulties are not overcome immediately, it will greatly affect student learning outcomes (Lestari et al., 2023). Student learning outcomes will be low or will decrease.

Learning outcomes are generally identified as a benchmark where students are considered to have mastered a subject matter. Moreover Learning outcomes are also a benchmark for success in learning activities as seen from how far learning goals are achieved (Putri Lismayana et al., 2023). There is a possibility that there are still learning outcomes that are not in accordance with students' abilities. For example, a student may get excellent grades but still have difficulty understanding the subject matter. This suggests that student learning outcomes may be substandard. Teachers should make sure their students fully understand the topic to avoid this.

Based on the observation activities that have been carried out at SDN Dawu 2 and the results of interviews with the homeroom teachers of grade III, it was found that out of a total of 15 students, as many as 8-9 students have been able to calculate and memorize basic multiplication 1 to 6 while the other 6 – 7 students still have difficulty in calculating basic multiplication and have only memorized multiplication 1 to 3. In other observation activities and based on the results of interviews with third-grade homeroom teachers at SDN Wonokerto 1, it was found that out of a total of 15 students, as many as 8-9 students were able to calculate and memorize basic multiplications from 1 to 10 while the other 6-7 students still had difficulties in calculating basic multiplication. This problem has an impact on the average learning outcomes of students where the average learning outcomes of grade III students at SDN Dawu 2 are 76 while the average learning outcomes of grade III students at SDN Wonokerto 1 are 74.66.

This is done because in the independent curriculum multiplication material has been taught in grade III where students have been introduced to the concept of basic multiplication operations and encouraged to memorize basic multiplication gradually. In fact, not all students memorize multiplication. The method applied by teachers, especially in the two schools that will be the subject of this study, is to memorize students independently. This method makes students less active and tends to be bored. Applying this method in the form of assignments, especially independently, can hinder students' activeness in learning the material given (Chaeroh et al., 2023).

This method of memorization may be suitable for students who have a strong memory, but it will be an obstacle for students who have a weak memory. The number of multiplications can affect the memory of each student. In certain time intervals, students receive a lot of information in the brain so that the absorbed information becomes heaped up and makes it difficult for them to dig up the incoming information early, which can cause students' memory to become weak (W.F. et al., 2021). Usually, there are students who experience nervousness when dealing with the teacher or nervous when working on exam questions. If this happens, it will affect students' memory. To address this problem, the researchers tried to apply a new approach. The Jarimatika method is one of the approaches that can be applied as a solution. Using a finger to perform arithmetic operations including addition, subtraction, multiplication, and division is known as the Jarimatic method. Students don't have to worry about forgetting a certain multiplication formula when they use this strategy.

The Jarimatika method has almost the same principle as the abacus media. Both apply a system of fast methods in counting rather than memorizing. It's just that this Jarimatika method does not require tools in the form of objects so that its use becomes more effective and efficient. Therefore, the use of abacus media is increased with the Jarimatika method (Lanya et al., 2020). The Jarimatika method at the elementary level is more suitable for basic multiplication. For higher multiplication, there will be additional certain formulas. This can be further studied at the next school level. The use of this Jarimatika method can not only help students in terms of memorizing basic multiplication but can also help teachers to overcome difficulties in their students. The use of this Jarimatika method is quite effective and efficient because it does not require strong tools and memorization. Students need to understand the concept and use their fingers so that students don't have to worry if they suddenly forget the basic rules that have been memorized beforehand.

Another strategy needs to be used considering the problems that have been mentioned to help children who have difficulty memorizing basic multiplication. To overcome these problems, the researcher is interested in conducting a study entitled "The Effect of the Use of the Jarimatika Method on the Learning Outcomes of Multiplication of Grade III Elementary School Students".

2. RESEARCH METHOD

With a posttest-only control design and a quasi-experimental methodology, this study uses a quantitative approach. Two groups participated in this study: a control group of third-grade children at SD Negeri Wonokerto 1 who were not exposed to the Jarimatika approach, and an experimental group of children at SD Negeri Dawu 2 who were exposed to the Jatimatiku method. The aim of the study was to ascertain how much the experimental group would be affected by the treatment compared to the control group. The thirty students were included in the research population, which consisted of fifteen third-grade students from SD Negeri Dawu 2 and fifteen third-grade students from SD Negeri Wonokerto 1. The entire population of 30 students served as a research sample. Non-probability sampling with saturated sampling type is the sampling strategy used in this research. Since the sample represents the entire population, this technique was chosen. In this study, data were collected through a post-test consisting of multiple-choice questions, both from the experimental group receiving therapy and the control group not receiving therapy. A series of tests measuring validity, reliability, discriminatory, and difficulty level were assigned to multiple-choice questions of varying difficulty levels for the purposes of this study. Independent sample t-tests are used for hypothesis testing as part of the data analysis technique, along with preliminary tests (normality and homogeneity tests). The series of tests will be carried out with the help of the SPSS 25 application.

a. Test Instrument Test
   1) Validity Test
      The instrument is said to be valid if it meets the significance level of 0.05 with the condition that $r_{\text{is calculated}} \geq r_{\text{table}}$. This validity test uses *the Pearson Product Moment correlation technique.*
   2) Reliability Test
      The instrument is said to be reliable if it meets the minimum criteria of "adequate" with a range of ≥ 0.41. This reliability test uses the *Alpha Cronbach formula.* The reliability categories of instruments can be seen through the following table:

Table 1. Reliability Categories

Correlation Coefficients	Reliability Categories
0,81 – 1,00	Very high
0,61 – 0,80	Tall
0,41 – 0,60	Enough
0,21 – 0,40	Low
0,00 – 0,20	Very low

   3) Difficulty Level
      The level of difficulty of the questions is observed from how capable the students are in solving the questions. The difficulty level of the instrument can be seen through the table below:

Table 2. Difficulty Category

Difficulty Index	Difficulty Category
0,00 – 0,30	Difficult
0,31 – 0,70	Keep

0,71 – 1,00	Easy

4) Differentiation
The range of values obtained is at least ≥ 0.21 which is included in the "sufficient" category. Question items can be used if they have a positive value differential. If the difference is negative, then the question item cannot be used.

Table 3. Category Differentiation

Differentiation Index	Category Differentiation
Negative	No differentiation (unusable)
0,00 – 0,20	Ugly
0,21 – 0,40	Enough
0,41 – 0,70	Good
0,71 – 1,00	Very good

3. RESULTS AND DISCUSSION

Prerequisite tests, including normality and homogeneity tests, are performed before hypothesis testing. Here are the results of the data analysis:

a. Prerequisite Test

1) Normality Test

This study used the Shapiro-Wilk test because the sample size was limited (less than 50). Instruments that are distributed regularly have a significance value above 0.05. This normality test determines whether the data from both samples are distributed regularly. The results of the Posttest of third grade students of SD Negeri Dawu 2, the experimental group, and SD Negeri Wonokerto 1, the control group, became the basis for this normality test. Here are the normality test results for the data from both samples:

Table 4. Normality Test Results for Posttest

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Kelas	Statistic	df	Sig.	Statistic	df	Sig.
Hasil Belajar Perkalian Siswa	Kelas Eksperimen	,184	15	,183	,909	15	,130
	Kelas Kontrol	,159	15	,200*	,909	15	,129

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Based on the normality test using the Shapiro Wilk test on SPSS 24, the data of the two samples had a significance value of 0.130 and 0.129, both > 0.05. Data is distributed normally.

2) Homogeneity Test

The homogeneity test ensures that the two sample groups are similar. Two samples are said to be homogeneous if the significance value exceeds 0.05. This study uses the Levene test. Homogeneity test results for post-test data from the experimental and control groups:

Table 5. Homogeneity Test Results for Posttest

Test of Homogeneity of Variances

Hasil Belajar Perkalian Siswa

Levene Statistic	df1	df2	Sig.
1,476	1	28	,235

Based on the results of the homogeneity test using the Levene Test in SPSS 24, it can be seen that the data from the two samples has a significance value of 0.235 where > 0.05 so that it can be concluded that the two samples are homogeneous.

b. Hypothesis Test

Independent Sample T-Test

The independent sample t-test hypothesis test compared the post-test results of the experimental group receiving therapy with the control group not receiving the therapy. Hypothetical results of independent sample t-test:

Table 6. Independent Sample T-Test Hypothesis Test Results Posttest

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Hasil Belajar Perkalian Siswa	Equal variances assumed	1,476	,235	3,465	28	,002	16,333	4,714	6,677	25,990
	Equal variances not assumed			3,465	26,041	,002	16,333	4,714	6,644	26,022

The SPSS 24 independent sample t-test hypothesis test showed 0.002, below 0.05. Thus, the experimental and control groups had different post-test results. As a result, H0 is rejected and H1 is accepted.

To ensure the achievement of learning objectives efficiently and successfully, teachers use various strategies and tactics in learning activities. Because learning activities are considered complete if the learning objectives are achieved, the choice of learning techniques is very important. Teachers must develop their teaching strategies before learning activities (Ramdani et al., 2023). The Jarimatika approach is one of the learning strategies used by the researcher in this study. Mathematical calculations including addition, subtraction, multiplication, and division can be solved using the Jarimatika approach. The Jarimatika method is an innovative learning method to optimize Mathematics learning process, especially related to calculation operations at the elementary level (Makarim et al., 2024). The Jarimatika method is a simple method because students only need fingers as a tool in the form of concrete objects to calculate.

The application of the Jarimatika method in multiplication learning activities is quite simple. This Jarimatika method can be used for multiplication of 2 to 9. In terms of practice and concept, a 2 to 5 multiplication is different from a 6 to 9 multiplication. Multiplication 2 to 5 uses the concept of repeated summation, while multiplication of 6 to 9 uses the concept of place value. Using this method, students are taught to calculate in an easy and quick way but still conceptualize so that students do not have to feel difficult in memorizing basic multiplication operations. In addition, students only need to use their fingers by combining predetermined patterns. According to Jean Piaget's (1952) theory of learning, students from the age of 7 to 11 will learn to use concrete objects to support their understanding (Isrok'atun & Rosmala, 2018).

The Jarimatika method has several advantages compared to other methods/media so that it can make it easier for students and teachers in learning activities. The advantages of using the Jarimatika method include (Salsinha et al., 2019):

1) This method focuses on student comprehension rather than student memorization.
2) Learning activities become more interactive because students can use their fingers directly.
3) The Jarimatika method can help with calculations without the need to use calculation tools and is easy to carry around so that it can be used anywhere and anytime, even during exams.

In addition to having advantages, the use of the Jarimatika method also has disadvantages. The disadvantage of using this Jarimatika method is that it is more suitable for basic multiplication due to the limitation of the number of fingers. So the limited number of fingers causes the Jarimatika method to be less suitable for multiplication with larger numbers (Robainah et al., 2022).

Learning outcomes are skills that students gain from involvement in educational activities; These achievements can be evaluated and measured. Another way to characterize learning outcomes is as a reflection of the work that has been done. Thus, students' learning efforts affect the results. Internal and external factors can affect student learning. External variables come from outside the student, while internal influences come from within the student. These characteristics are what help achieve learning goals.

a. Internal Factors

1. Student Preparation

Students need to prepare themselves mentally and physically before starting learning activities. These two elements are important because they have the potential to affect student learning success. Student learning outcomes will improve if they are ready to learn (Sari & Ritonga, 2021). Maintaining physical fitness is one way to prepare physically. Students will be able to participate in learning activities more successfully and achieve better learning outcomes if they study in healthy conditions. On the other hand, students who study in sick conditions will not be able to participate in the learning process well, which will result in less-than-ideal learning outcomes.

Similar to physical preparation, psychological preparation is also very important. If students' mental health is well maintained, then students will be able to focus more on paying attention to learning. Of course, if students can focus on studying well, then students will be able to absorb learning materials well as well so that student learning outcomes can increase. On the other hand, if students' mental health is not well maintained, it will be more difficult for students to focus during their studies. This will of course also affect the absorption of learning materials in students so that student learning outcomes can decrease. Controlled mental health can strengthen students in dealing with problems and support students in exploring their abilities optimally (Winei et al., 2023).

2. Student Interests

Learning outcomes, which measure students' level of understanding, are influenced by their interest in the subject. The material provided will be easy for students to understand if they are involved in listening to the teacher's explanation. Student learning outcomes will increase if they understand the material taught. On the other hand, students will have a hard time understanding the material if they are not actively engaged. Students' learning outcomes will decrease if they do not understand the material being taught. So that high student learning outcomes are influenced by students' learning interests, while low student learning outcomes are influenced by students' lack of interest in learning (Widiati et al., 2022).

3. Student Motivation

Motivation is also known as motivation. Motivation is the motivation of students to learn, both inside and outside the classroom. Intrinsically motivated students are more engaged in learning. Motivated students learn better. However, students who are not motivated will be less engaged in learning. This can reduce learning outcomes. Thus, learning outcomes depend on the motivation of the students (Nugroho & Attin Warmi, 2022).

b. External Factors

1. Family Environment

The family environment is an important factor in improving student learning outcomes because everything starts from the family environment. The relationships in the family will be brought by students to the school. Relationships between family members are a determining factor in learning completion (Siregar, 2021). If the relationship established in the family is in good condition, then students will be able to concentrate more during learning activities at school so that student learning outcomes can be improved. On the other hand, if the relationship in the family does not go well, it will be difficult for students to concentrate during learning activities at school so that student learning outcomes may decrease.

In addition, support in the form of appreciation and assistance in completing tasks by parents is also important. Parents can contribute to the learning process at home such as helping with homework, school projects, repeating learning that has been explained by the teacher in simpler language so that children understand the material better, and so on so that student learning outcomes can be maximized. Parents play the role of teachers, guides, and motivators. In addition, parents can also introduce new things in a concrete way to their children (Rachman & Yamin, 2023).

2. School Environment

In addition to the family environment, the school environment is also an important factor that can affect student learning outcomes because school is the second place to pursue education. The school environment includes peers, teachers, learning activities, and facilities and infrastructure. These components must have the right role so that learning outcomes in students can increase.

Peers are usually considered the right friends to be with in everything. Not only suitable for playmates but also study friends. For parents, choosing friends for their children is very important because it can affect their learning outcomes. If students have peers to invite to learn together, then student learning outcomes can improve because they will share the knowledge they understand. Positive pressure from groups such as competing in achievements, group learning, and discussing can increase students' interest in learning and will affect their learning outcomes (Akbar & Aufa, 2024).

The role of teachers is no less important than the role of parents. The teacher is the second parent at school so the teacher is fully responsible for what is done and what happens to each student. To ensure efficient delivery and understanding of learning information, instructors need to master a wide variety of teaching techniques, media, and models. The success of the learning process is determined by the teacher, so its role in education is very important (Novitasari & Fathoni, 2022). Student learning outcomes can be improved if they understand the material presented. Teachers act as mentors and counselors, in addition to educators. To ensure students can focus during learning activities, teachers must be prepared to handle any issues that may arise in the classroom.

In order for students not to be bored and distracted by their personal lives, learning activities must be carried out in a comfortable environment, both inside and outside the classroom. Students tend to study passionately in a friendly classroom environment, which can improve their academic achievement. Learning activities can be started by providing an icebreaker in advance so that students are not too tense when participating in learning activities. In addition, icebreakers can also train students' concentration so that students will be better prepared to participate in learning activities. The use of ice breaking is also important to be given so that students become interested in carrying out learning activities (Zuhariyah & Fahmi, 2022).

Infrastructure and facilities play a balanced role in educational activities. The provision of infrastructure and supporting facilities can improve students' understanding of subject matter. Infrastructure and supporting facilities are needed so that learning activities can run as smoothly and efficiently as possible (Agustina et al., 2022). Students' learning outcomes will also increase if they can understand the material presented.

In addition to infrastructure and facilities, the learning approach also affects how well students absorb the material. To ensure students learn effectively and an engaging classroom environment, teachers must be able to choose the right teaching strategies. The use of interactive learning techniques is essential to increase students' enthusiasm when learning (Leuwol et al., 2023). The Jarimatika approach is one of the interactive learning strategies that can be applied.

This research is based on the theory of Zoltan Dienes (1971) which applies the principle of concretization and gradual learning which has 6 stages, namely:

a. Free Games

At this stage, students learn to calculate multiplications from 2 to 5 using a simple pattern that is used as a benchmark so that students can calculate accurately. Using this method, students can correctly calculate the basic multiplication from 2 to 5 without the need to cheat on their classmates' answers.

b. Games with Rules

At this stage, students start calculating multiplications of 6 to 9 using pattern rules with the simple formula of units and tens, so it takes students longer than the previous stage. Using this method, students can already calculate basic multiplications of 6 to 9 without the need to memorize again.

c. Identifying Trait Similarities

At this stage, students are already introduced to the various patterns applied to their fingers so that they feel more interested in trying the pattern where previously they only calculated manually without any patterns. Students know which pattern to use. Using this method, students are able to solve basic multiplication in the form of picture problems.

d. Representation

At this stage, students know that each finger has a value and can represent each number so that when calculating students do not have to imagine the number to be calculated. Students can use paper and pencils/ballpoint pens as additional tools. After being introduced to the Jarimatika method, students become able to solve multiplication calculation operations in story/everyday life problems.

e. Symbolization

During the treatment, after being introduced to the pattern used, students tried independently by answering questions in the form of multiplication questions given. After the treatment was done, the students who initially always looked at their friends' answers, they focused on working on their own questions.

f. Formalization

In this study, students could not do multiplication problems without using finger aids. This is because this method is a new method and takes longer for students to calculate without the help of fingers.

Jarimatika's approach has been proven to help students in calculating multiplication operations in the experimental group of third-grade students at SD Negeri Dawu 2. This is shown by the improvement of post-test learning outcomes after treatment with the Jarimatika approach. The third grade students of SD Negeri Dawu 2 looked enthusiastic during the treatment activity and wanted to try the Jarimatika approach that had been taught for the calculation of basic multiplication. This shows how Jarimatika's approach can arouse children's interest in learning how to do simple multiplication calculations. Students become more enthusiastic because in this Jarimatika method there are diverse and unique patterns. In addition, you can also find students who can't wait to learn the next multiplication right away. After being given treatment, students become more independent in doing Posttest questions. Students become more focused on calculating their own assignments without looking at their friends' answers. By using this Jarimatika method, student learning outcomes can be improved.

In grade III students of SD Negeri Wonokerto 1 as a control group, it was proven that Posttest learning outcomes without treatment decreased and only 2 students experienced an increase in learning outcomes. Without medication, students have difficulty solving Posttest questions and tend to prefer to see answers from their classmates. There were students who discussed with my classmates to get answers. There are also students who use dice to get answers.

Based on results *posttest* obtained this study is comparable to a study entitled "The Influence of the Jarimatika Method on the Learning Outcomes of Multiplication of Grade III Students of SD Inpres Sikumana 3 Kupang" which showed that the average score of grade III students in the experimental class increased after being given *treatment* which was initially 57.41 increased to 82.59 (Bete et al., 2021). This shows the influence of the use of the Jarimatika method on student learning outcomes.

The application of the Jarimatika method has a significant impact on student learning outcomes in elementary schools in mathematics, multiplication, and grade III, in accordance with a number of studies and tests, including instrument tests, prerequisite tests, and hypothesis tests. The increase in the average score of the experimental class after the application of the Jarimatika approach shows this. Students can calculate more quickly and accurately by using the Jarimatika approach to help them solve multiplication.

4. CONCLUSION

The purpose of this study is to find out whether the use of the Jarimatika method has an impact on student learning outcomes in mathematics classes for grade III multiplication in elementary school. It is evident from the research that the learning outcomes of students in mathematics classes for grade III multiplication in elementary school are influenced by the application of the Jarimatika technique. This is shown by the fact that after the Posttest, the learning outcomes of students in the experimental group that applied the Jarimatika approach increased, while those in the control group who did not use the method decreased. As a result, H1 was accepted and H0 was rejected, which shows that Jarimatika's approach has a major impact on student learning outcomes in mathematics classes for grade III multiplication in elementary school. It shows how the Jarimatics approach can assist students in completing arithmetic tasks involving multiplication.

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Integrating Educational Games in Problem-Based Learning to Enhance Conceptual Understanding in Mathematics: A Study of Grade VII Students at MTsN 1 Pekanbaru

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ABSTRACT

This study aims to describe the application of educational games using the Problem Based Learning (PBL) model in mathematics learning to improve the understanding of mathematical concepts of grade VII students of MTsN 1 Pekanbaru. The background of this study is the low understanding of mathematical concepts of students as shown through daily test results data in grade VII.5, where only 48.65% of students achieved the Minimum Completion Criteria (KKM) of 87. This study is a Classroom Action Research (CAR) conducted in two cycles with each consisting of planning, implementation, observation, and reflection stages. The research instruments include teacher and student observation sheets and mathematical concept understanding tests. The PBL model is combined with educational game media in the form of traditional games such as snakes and ladders and setatak. The results of the study showed a significant increase in students' understanding of mathematical concepts. In cycle I, the percentage of student understanding was in the "good" category with an average value of 79.05%, while in cycle II it increased to 89.05% and entered the "very good" category. Thus, the application of educational games based on the PBL model is effective in improving students' understanding of mathematical concepts.
Keywords: Educational Games, Problem Based Learning, Mathematical Concept Understanding, Mathematics, CAR

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1. INTRODUCTION

As knowledge basic mathematics hold role important in support understanding to field other sciences (Nurmalia et al., 2019: 70) . Science mathematics own mark high usability in help finish various problem in life real (Yolanda & Wahyuni, 2020: 2) . Mathematics emerged from the fruit from the thinking process humans related to ideas, processes, and reasoning abilities (Kusumawardani et al., 2018: 588) . One of the target main from mathematics learning , as listed in Attachment to Minister of Education and Culture Decree Number 58 of 2014 , that is For equip students with ability in understand concepts mathematical in a way In-depth . This includes competence in explaining the relationships between concepts and applying them appropriately to solve problems (Wahyuni & Sholichah, 2022: 66) . Understanding concepts is the main foundation for thinking to solve a problem. (Love et al. , 2019) . From the description above can withdrawn conclusion that mathematics considered as product from exercise think man which focuses on ideas, processes, and reasoning skills.

In mathematics learning, understanding concepts is the main goal to equip students with the ability to explain the relationships between concepts and apply them effectively. in finish problem . Understanding this concept is also an important basis for thinking about solving various mathematical problems. Hadi & Umi Kasum, (2015: 60) states that understanding mathematical concepts is the main basis for thinking in solving various problems, both in mathematics and everyday life. This means that the ability to understand mathematical concepts not only helps solve problems or questions in mathematics lessons, but can also be applied in everyday situations, such as decision-making, time management, or financial calculations.

Mastering a concept plays a crucial role in helping students analyze problems more deeply and find appropriate solutions. By understanding concepts well, students will be better prepared to learn subsequent material that requires higher-order thinking skills (Ntjalama et al., 2020).

However, in practice, one of the main obstacles to mathematics learning is students' poor understanding and application of mathematical concepts.

According to information obtained researchers through interview with Mathematics subject teacher for class VII $_5$ MTsN 1 Pekanbaru on December 23, 2024, information obtained is as following:

1. Standard Criteria Minimum Completion (KKM) which has set by the school for grade 7 is 87.
2. Learning methods that are often used by teachers in class are *Discovery Learning*, *Project Based Learning*, and usually use the help of learning videos too.
3. Student No too focus on lessons taught by teachers, and a number of from they seen evaporate or chatting with Friend classmates moment learning ongoing
4. Students are embarrassed to ask questions because they're confused about what they really want to know. After several presentations of the material presented by the teacher, students are confused about which part they really want to know. ask because most of them still difficulty in immediately understanding parts of the material.
5. The level of understanding of most students is good and some students are even very good, only a small number or at most half of the students in a class do not understand the mathematics material while the teacher is teaching.
6. Grade 7 students still have limitations in mathematical literacy, so that in moment question mathematics served by the teacher in form question story It becomes difficult for them to understand the question and it is also difficult to find what problem needs to be solved in the question.
7. Students do not fully understand draft base from material mathematics, things This cause student No do exercise question, so that they difficulty for understand different questions from examples given.
8. Students are too afraid to learn mathematics, so they don't understand the concept and find it difficult to explain the concept again.

Based on results observations made on December 23, 2024 conditions in Class VII.5 MTsN 1 Pekanbaru, where the KKM is quite high (87), is not fully achieved by all students due to various factors. The learning methods used, such as *Discovery Learning* and *Project- Based Learning,* are innovative, but students often lack focus during learning. They tend to have difficulty understanding the material, especially because their mathematical literacy is still low, which is seen from their inability to understand story problems. Students are also embarrassed to ask questions because they do not clearly understand which part is confusing them. Some students have a good understanding, but there are about half of the students who have difficulty understanding basic mathematical concepts due to a lack of practice questions and fear of mathematics lessons. This results in them being unable to apply concepts to everyday life.

Table 1.Completion Data Student Based on Student UH Results Class VII.5 MTsN 1 Pekanbaru

Category	Amount Student	Percentage
Completed (≥ 87)	18	48.65%
No Completed (< 87)	19	51.35%
Total	37	100%

Source: Guru mata lesson Mathematics Class VII.5 Mtsn 1 Pekanbaru

Of the 37 students, only 18 students (48.65 %) completed it, while 19 students (51.35%) had not. achieve KKM. Results This show that a number of big students Still difficulty in absorb material lessons, so that required approach more teaching capable increase quality learning next.

The 2022 PISA results show that the pandemic has had a global impact on learning outcomes, with average mathematics literacy scores declining. by 21 points. However, Indonesia managed to suppress the score decline to only 13 points, better than the international average. Furthermore, Indonesia's ranking in the 2022 PISA (Philosophy of International Student Assessment) improved by 5-6 positions compared to 2018, reflecting the resilience of the education system in overcoming learning loss due to the pandemic . (Ministry of Education, Culture, Research, and Technology, 2023 : 8) . This shows that despite facing challenges, education in Indonesia continues to strive to recover and develop.

Seeing the situation and conditions that have been described, a learning approach is needed that encourages students to be more involved in a way direct in the learning process teaching . The learning model applied needs to provide ample opportunities for students to express mathematical ideas, develop thinking skills, and provide opportunities for them to develop problems given by the teacher (Wahyuni & Sholichah, 2022: 67) . One of the learning models that can encourage activity student is a *Problem Based Learning* (PBL) learning model .

PBL is a learning method where students learn through problem solving, thinking collaboratively in groups, and using relevant information to solve the problem (Syawaly & Hayun, 2020: 42) . *The Problem Based Learning* (PBL) model emphasizes activity learning that focuses on problem solving. Some of the advantages of implementing the PBL model include: (1) reducing student learning difficulties through group learning, (2) developing communication skills through presentation activities and discussions of work results, (3) having scientific activities in groups, (4) understanding the material through the context of existing problems, (5) increasing student insight optimally through learning activities, and (6) helping students develop skills in solving everyday problems (Rahmadani et al., 2023: 130) . In the PBL model, the teacher plays a role as facilitator on duty guide as well as supervise activity Study students , so that capable push participation active And strengthen interaction they during the learning process ongoing (Portuna et al., 2025) . The PBL model is seen effective in help student increase understanding against draft mathematics. Effectiveness This appear Because in application of the model , students pushed For in a way independent look for solution , do analysis , as well as finish problems faced (Ariawan & Zetriuslita, 2023) . Based on presentation previously, it can be concluded that PBL is a learning method that emphasizes problem-solving through group work, the use of relevant information, and the development of communication skills. This model helps students understand material in real-world contexts, increases insight, and trains skills in solving everyday problems.

In addition to learning models, media are needed that can support the learning process to attract students' interest, motivate them, and prevent them from getting bored. boredom during learning. With thus interest as well as motivation student in Study can grow better, reduce boredom, and make things easier understanding draft. Intended media One of them is the educational *game.* According to Yunus et al., (2015: 59) *game* is a form activities that involve game or competition , game often depicted in the form of activities that have arrangement still or part directed , usually intended For entertainment And sometimes used as tool learning . According to Amami Pramuditya et al., (2017: 77) *A game* is a type of activity in the form of a game or competition. *Games* can be interpreted as as a structured or semi-structured activity, usually done for entertainment and sometimes used as a learning tool. According to Vitianingsih, (2017: 25) One of the main advantages of educational *games* is their ability to visualize real-world problems. In this regard, educational concepts can be presented in a more interactive and engaging manner, motivating students to actively participate in the learning process. In connection with the above [15] put forward that educational game encourage desire know participant educate to something topic as well as given the chance For explore it more in . The motivation that arises No solely Because award external or confession from other people, but Also Because given award intrinsic.

Based on the background that has been described, the researcher is interested in carrying out research with the title **"Integrating Educational Games in Problem-Based Learning to Enhance Conceptual Understanding in Mathematics: A Study of Grade VII Students at MTsN 1 Pekanbaru".**

2. RESEARCH METHOD

This research was designed as a Classroom Action Research (CAR) involving two cycles, where each cycle covered the stages of planning, implementation, observation, and reflection (Susilowati, 2018). The study took place at MTsN 1 Pekanbaru with participants from class VII.5 during the second semester of the 2024/2025 academic year.

The instructional tools included teaching modules, student worksheets, textbooks, and assessment instruments. Data were gathered through written tests, classroom observations, and documentation. The tests assessed students' understanding of mathematical concepts, while observation sheets were employed to monitor the activities of both teachers and students.

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For data analysis, a descriptive approach was applied. Quantitative data were analyzed by comparing students' test results across the two cycles, whereas qualitative data described the teaching and learning processes in the classroom. The criteria for success were determined by an individual minimum score of 87 and a class mastery level of at least 75%. Improvements from one cycle to the next served as indicators of the intervention's effectiveness.

3. RESULTS AND DISCUSSION

The increase in understanding of mathematical concepts in cycle I and cycle II can be observed through the results of understanding of mathematical concepts in cycle I, by comparing the level of understanding of concepts from the cycle II mathematics test of class VII.5 students of MTsN 1 Pekanbaru. The following analysis presents a picture of the increase in understanding of mathematical concepts of class VII.5 students of MTsN 1 Pekanbaru in both cycles.

Analysis of the Achievement of KPM Indicators in the Mathematical Concept Understanding Test I

The results of the test in cycle I were obtained through the implementation of the final test of cycle I (Mathematical Concept Understanding Test I). Through this test, it is hoped that the limits of students' understanding of abilities in understanding mathematical concepts have improved. An analysis of the results of the final test of cycle I (Mathematical Concept Understanding Test I) is presented in Table 2. below:

Table 2. Classification of the Quality of Students' Understanding of Mathematical Concepts in Cycle I

No.	Indicator	Understanding Draft Mathematical		
		Total Score	KPM %	Classification of Understanding
1	Restating the concept.	135	91.22	Very good
		97	65.54	Enough
2	Classify objects according to certain properties (according to the concept).	103	69.54	Enough
		126	85.14	Good
3	Provide examples and non-examples of the concept.	124	83.78	Good
	AMOUNT	585	79.05	Good

Source: Data processed by researchers

The results of cycle I include the final test of cycle II, namely the Mathematical Concept Understanding Test II. This test is intended to determining the level of students' ability to understand mathematical material conceptually has improved. The analysis of the final test results in cycle II is presented in Table 3 below.

Table 3. Classification of the Quality of Students' Understanding of Mathematical Concepts in Cycle II

No.	Indicator	Understanding Draft Mathematical		
		Total Score	KPM %	Classification of Understanding
1	Restating the concept.	137	92.57	Very good

		135	91.22	Very good
2	Classify objects according to certain properties (according to the concept).	135	91.22	Very good
		127	85.81	Very good
3	Provide examples and non-examples of the concept.	125	84.46	Good
	AMOUNT	659	89.05	Very good

Source: Data processed by researchers

After analyzing each indicator, the average understanding of mathematical concepts at the initial score, TKPM I and TKPM II is presented as follows:

Table 4. Classification of the Quality of Students' Understanding of Mathematical Concepts in Cycle II

	TKPM I	**TKPM II**
Total score all over student	585	659
Average	79.05	89.05
Criteria	**Good**	**Very good**

Source: Data processed by researchers (Appendix H)

Referring to the data presented in table 4.3 above, shows that students' understanding of mathematical concepts as a whole, both from the initial test scores to TKPM I and from TKPM I to TKPM II. The most striking improvement was seen in the average KPM score between cycles I and II. This improvement occurred because the learning process in cycle I was not fully implemented as expected. Several students still struggled to understand the material, the classroom atmosphere was less than conducive, and the learning process did not fully align with the plan outlined in the module.

In contrast, during the second cycle, the learning process proceeded according to the plan and expectations outlined in the module. Students began to become accustomed to using educational *games* using the PBL model implemented by the teacher. They also demonstrated greater commitment to learning activities and did not engage in activities outside the context of the lesson. Evidence of this improvement was evident from observations of teacher and student activities, as well as from the increase in total student scores. These findings indicate that improving the implementation of learning demonstrate a beneficial influence on students cognitive ability to absorb mathematical concepts through the application of educational games with the Problem Based Learning model.

To assess the extent to which become the steps of the *Problem-Based Learning model* , using the educational *game* that has been designed , align with actual classroom implementation, we can analyze findings from using teacher and student observation sheets. This information is presented in the following table, which contains the findings obtained through the analysis of teacher and student actions in each cycle during the learning activities.

Table 5. Analysis of teacher observation sheets

Meeting	indicator						Amount	POG	CATEGORY
	1	2	3	4	5	6			
Meeting 1	3	1	3	3	3	3	16	88.89	Good
Meeting 2	3	2	3	3	3	3	17	94.44	Very good

Meeting 3	3	2	3	3	3	3	17	94.44	Very good

Source: Data processed by researcher (Appendix C)

Teacher observations showed improvement and consistency in the implementation of learning. The score of meeting 1 was 88.89 % (good) increased to 94.44% (very good) in meetings 2 and 3. This indicates the effectiveness of the teacher's learning approach and strategies.

Table 6. Analysis of Student Observation Sheets

Meeting	indicator							Amount	POST	CATEGORY
	1	2	3	4	5	6	7			
Meeting 1	2	3	3	3	2	2	1	16	76.19	Enough
Meeting 2	2	3	3	3	2	2	1	16	76.19	Enough
Meeting 3	2	3	3	3	2	2	3	18	85.71	Good

Source: Data processed by researcher (Appendix C)

Although not significant, there was an improvement in student activity at the third meeting , indicating that they were becoming accustomed to implementing educational *games* using the PBL model. However, student engagement still needs to be improved for optimal results.

Based on the analysis results, the average student's KPM for all indicators also increased. This can be seen from the average score of mathematical concept understanding in cycle II which increased from cycle I. The average score of the mathematical concept understanding test in cycle I was 79.05% with a good level of understanding, and the average score of the mathematical concept understanding test II was 89.05% with a very good level of understanding. This means that in this action, students' mathematical concept understanding increased after the implementation of educational *games* using the PBL model during the activity

Refers to analysis of the teacher observation sheet, there was an improvement and consistency in practice implementing teaching strategies. The score in the first meeting reached 88.89 % with a good category and increased to 94.44% with a very good category in the second and third meetings. This reflects that the learning approach and strategies implemented by the teacher were running effectively. Analysis of the student activity sheet also showed an improvement during the learning process. Which is seen from the first and second meetings obtained a score of 76.19 % with a sufficient category, and the third meeting reached a score of 85.71% with a good category. Although not significant, there was an improvement in student activity in the third meeting. This indicates that students are starting to get used to the implementation of educational *games* using the PBL model. However, student engagement still needs to be improved.

4. CONCLUSION

If we look at the findings that have been analyzed obtained from data analysisin this study, it was the findings of this study indicate that education *games* using the PBL model can improve the learning process and increase the understanding of mathematical concepts of class VII.5 MTsN 1 Pekanbaru students during teaching and learning activities in the even semester in the year 2024/2025 academic year on the material of plane shapes and data analysis.

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The Digital Divide in Post-Pandemic Education: Perceptions of Urban and Rural EFL Teachers in Indonesia

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ABSTRACT

The COVID-19 pandemic acted as an unprecedented catalyst, forcing a global transition to online education and exposing deep-seated infrastructural and pedagogical vulnerabilities. This study investigates the lasting perceptions of this shift among English as a Foreign Language (EFL) teachers in Indonesia, focusing on the persistent challenge of the urban-rural digital divide. Employing a qualitative case study approach, this research explores the experiences of four junior high school English teachers in Pontianak Regency—two from urban and two from rural schools. Data were gathered through semi-structured interviews and document analysis. The findings reveal a significant dichotomy in teacher perceptions shaped by geographical location. Urban teachers, while initially optimistic, developed negative perceptions due to pedagogical frustrations and declining student engagement. In contrast, rural teachers held overwhelmingly negative perceptions from the start, citing insurmountable barriers related to internet access, device availability, and lack of digital literacy. The study concludes that the emergency remote teaching experience has solidified teacher perceptions that a one-size-fits-all approach to educational technology is untenable in a diverse landscape like Indonesia, highlighting an urgent need for context-aware policies and equitable infrastructure development in the post-pandemic era.

Keywords: Digital Divide, Post-Pandemic Education, EFL Teacher Perception, Online Learning, Urban-Rural Disparities, Educational Technology

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1. INTRODUCTION

The COVID-19 pandemic necessitated an abrupt and universal shift to Emergency Remote Teaching (ERT), a crisis-response mode distinct from planned online learning (Hodges et al., 2020). While many educational systems have since returned to in-person instruction, this period has left a lasting imprint on educators' perceptions of technology's role in the classroom. This experience did not create new inequalities but rather cast a harsh light on pre-existing disparities, particularly the digital divide between urban and rural communities (UNESCO, 2020). In Indonesia, a nation characterized by vast geographical and socioeconomic diversity, this divide became a critical barrier to educational continuity (Anwar & Adnan, 2020).

Teacher perception – their beliefs and attitudes – is a powerful determinant of their classroom practice. According to the Technology Acceptance Model (TAM), perceived usefulness and perceived ease-of-use are key predictors of technology adoption (Davis, 1989). However, during the pandemic, adoption was not optional. This forced transition often bypassed the crucial step of building teacher confidence, leading to negative experiences that solidified into lasting negative perceptions (König et al., 2020). Furthermore, the Technological Pedagogical Content Knowledge (TPACK) framework suggests that effective technology integration requires a complex interplay of knowledge about technology, pedagogy, and content (Mishra & Koehler, 2006). The lack of preparation for ERT meant most teachers lacked the holistic TPACK needed for success, contributing to widespread frustration. The digital divide encompasses more than just access to the internet; it includes disparities in device availability, digital literacy, and technical support (van Dijk, 2020). In many developing nations, this divide falls sharply along urban-rural lines (Lembani et al., 2020). Rural schools often contend with unreliable electricity, poor internet connectivity, and a student population from lower socioeconomic backgrounds, making online learning nearly impossible (Anwar & Adnan, 2020; Bonal & González, 2020). Studies from the pandemic era consistently show that students in rural areas experienced greater learning loss due to these infrastructural barriers (Ferri et al., 2020). This places an immense burden on rural teachers, who must innovate with limited-to-no resources, often leading to stress and burnout (Kim & Asbury, 2020).

Perceptions formed during a period of crisis, stress, and inadequate preparation are likely to shape future attitudes towards digital learning. Understanding these lasting impressions is vital for developing effective and equitable educational policies in the post-pandemic landscape. While the initial crisis has passed, the challenges it revealed – inadequate infrastructure, lack of training, and socioeconomic barriers – remain pressing issues (Sari & Suryani, 2021). **Despite extensive research on the immediate impacts of ERT, there remains a significant gap in understanding the *enduring perceptions* of teachers, particularly how these perceptions were shaped by pre-existing regional disparities like the urban-rural digital divide in a diverse context such as Indonesia.** Previous studies have often focused on the technical challenges or immediate responses, but fewer have delved into the long-term shifts in teacher mindset post-pandemic, especially considering the varied experiences between urban and rural educators.

This study addresses this context by examining the enduring perceptions of EFL teachers in Pontianak Regency, a region representative of Indonesia's urban-rural contrasts. By analyzing their experiences, this research aims to provide actionable insights for creating more resilient and inclusive educational systems. The study is guided by the following research questions:

1. What are the lasting perceptions of EFL teachers regarding the shift to online teaching?
2. What online teaching tools were viable, and what determined their use?
3. What were the fundamental challenges faced by EFL teachers, and how did these differ between urban and rural settings?

2. RESEARCH METHOD

A qualitative case study design was utilized to facilitate an in-depth exploration of the teachers' lived experiences within their specific contexts (Creswell, 2009). This approach was chosen for its strength in uncovering the rich, nuanced meanings individuals ascribe to a phenomenon, which is essential for understanding the complexities of teacher perception.

A. Participants

Four junior high school EFL teachers in Pontianak Regency were purposefully selected for this study. The selection was stratified to ensure representation from different contexts: two teachers were from well-resourced urban schools (Mempawah and Pontianak) and two were from under-resourced rural schools (Singkawang and Kubu Raya). Participants were aged 25-30 with 2-4 years of teaching experience.

B. Instruments and Data Collection

The primary data were collected through semi-structured, one-on-one interviews conducted via video call. This method allowed for consistent questioning while providing the flexibility to probe emergent themes (Patton, 2014). Each interview lasted approximately 20-40 minutes, was screen-recorded with consent, and transcribed verbatim. To triangulate findings, participants also shared supplementary documents, such as modified lesson plans and learning materials used during the online teaching period.

C. Data Analysis

The data were analyzed using inductive thematic analysis. The researcher immersed himself in the transcripts to identify recurring patterns and concepts. These were systematically coded and then organized into broader themes that directly answered the research questions. A comparative analysis was conducted between the urban and rural datasets to highlight key differences and similarities in their experiences and perceptions.

3. RESULTS AND DISCUSSION

The findings revealed a clear and consistent divide between the experiences of urban and rural teachers, shaping their perceptions, technology use, and challenges.

A. Lasting Perceptions of Online Teaching

The perceptions formed during the pandemic were deeply ingrained and directly correlated with the teachers' teaching environment.

1. Urban Teachers: From Optimism to Pragmatic Skepticism

Urban EFL teachers initially approached online teaching with optimism, viewing it as a new opportunity, but their enthusiasm quickly evolved into pragmatic skepticism. This shift was primarily due to unforeseen pedagogical challenges rather than technical limitations, leading them to perceive online tools as supplementary rather than a complete replacement for in-person instruction.

- Teacher 1 recalled, "At first, I had a positive perception... but that perception turned negative with the many problems teachers face... The most influential factor is the unpreparedness."
- Teacher 2 added, "My perspective becomes negative when the implementation process is not as easy as expected. The need for adaptation is so complicated." This indicates that while urban teachers had access to the necessary infrastructure, the lack of readiness in pedagogical strategies for online environments led to frustration and a more critical view of ERT's effectiveness, aligning with findings on teacher burnout and disengagement (König et al., 2020; Kim & Asbury, 2020).

2. Rural Teachers: A Confirmation of Impossibility

In stark contrast, rural EFL teachers held overwhelmingly negative perceptions of online teaching from the outset, views that were merely solidified by their actual experience. For them, online learning was not a matter of pedagogical challenge but an existential impossibility due to insurmountable infrastructural and socioeconomic barriers.

- Teacher 3 stated, "I have a negative perspective... things are difficult due to the inadequate support factors at the school where I teach."
- Teacher 4 in the most remote location powerfully articulated, "I do not have the slightest positive perspective on online teaching... we live in remote villages with minimal internet access and telecommunications infrastructure."
  Their experiences underscore the profound impact of the urban-rural digital divide, where basic access to technology and connectivity remains a critical impediment, turning the mandate for online teaching into a source of immense stress and a symbol of policy detachment from local realities, as also observed by Anwar & Adnan (2020).

B. Comparative Analysis of Urban vs. Rural Teacher Experiences

To further illustrate the distinct experiences and perceptions, Table 1 provides a comparative overview of key aspects between urban and rural EFL teachers in Pontianak Regency.

Table 1. Comparative Overview of Urban vs. Rural EFL Teacher Experiences During ERT

Feature	Urban Teachers	Rural Teachers
Initial Perception	Optimistic, viewing ERT as an opportunity	Overwhelmingly negative, perceiving ERT as impossible
Shifting Perception	From optimism to pragmatic skepticism due to pedagogical challenges	Confirmed initial negative views due to foundational access barriers
Primary Challenges	Pedagogical issues (engagement, classroom management), digital competence gaps	Foundational access barriers (internet, devices, digital literacy, support)
Common Tools Utilized	Google Classroom, Google Meet (synchronous/asynchronous)	WhatsApp (makeshift), house-to-house teaching (non-digital)
Key Takeaway	Online tools are supplementary; in-person interaction is crucial	Online teaching is unviable without basic infrastructure

This table highlights the fundamental divergence in the ERT experience. Urban teachers, while facing their own set of challenges related to pedagogical adaptation and student engagement, operated within a functional technological environment. Their skepticism arose from the *quality* of online interaction and learning outcomes. Conversely, rural teachers were battling the *impossibility* of online learning itself, where the absence of basic infrastructure rendered most digital solutions moot. This stark contrast emphasizes that the digital divide is not merely about access but fundamentally alters the nature of educational challenges faced by educators, transforming pedagogical concerns into issues of basic survival in rural contexts.

C. Interpreting Findings in Light of Theory:

The experience of the urban teachers aligns with global reports on ERT, where initial optimism was often replaced by frustration due to a lack of pedagogical training and support, leading to teacher burnout and student disengagement (König et al., 2020; Kim & Asbury, 2020). Their journey highlights that access to technology is only the first step; effective integration requires deep pedagogical knowledge, as described in the TPACK framework (Mishra & Koehler, 2006). This study's urban teachers, despite technological access, grappled with the 'pedagogical content knowledge' aspect of TPACK, struggling to translate traditional teaching methods effectively into an online format and maintain student engagement. This implies that perceived usefulness (TAM) was hindered by a lack of pedagogical readiness, leading to negative attitudes despite technological availability.

The rural teachers' accounts provide a stark illustration of the digital divide's crippling effect on education (van Dijk, 2020). Their inability to use standard online tools and their resort to WhatsApp or house-to-house visits is a testament to their resilience but also an indictment of a system that fails to provide basic necessities (Anwar & Adnan, 2020). Their consistently negative perception was a logical conclusion drawn from an environment where the requirements for online learning were simply absent. This validates the argument by Hodges et al. (2020) that ERT should not be confused with, or judged by the same standards as, well-designed online education. For rural teachers, the very foundation of perceived ease-of-use (TAM) was non-existent due to infrastructural gaps, rendering the entire concept of online teaching impractical.

D. Contrast with Specific Prior Indonesian Studies:

While previous Indonesian studies, such as Sari & Suryani (2021) and Anwar & Adnan (2020), have highlighted the digital divide's impact on remote learning, this research further deepens our understanding by explicitly contrasting the *lasting perceptions* of teachers across urban and rural settings. Sari & Suryani (2021) documented the general challenges of infrastructure in Indonesia during the pandemic, and Anwar & Adnan (2020) focused on higher education. Our study contributes by providing a granular, qualitative insight into *junior high school EFL teachers'* enduring views, demonstrating how their geographical location fundamentally altered not just their experience but their post-pandemic educational philosophy. Unlike studies focusing on immediate responses, this research captures the solidified skepticism in urban areas and the confirmed impossibility in rural areas, offering a unique perspective on the long-term psychological and practical legacy of ERT in Indonesia's diverse educational landscape.

The pandemic, therefore, served as a nationwide, unsanctioned stress test of Indonesia's educational infrastructure. The results, as seen through the eyes of these teachers, indicate a systemic failure to support its most vulnerable populations.

4. CONCLUSION

The forced shift to online teaching during the pandemic has left a legacy of strong, context-dependent perceptions among EFL teachers in Pontianak Regency. The urban-rural divide was the single most significant factor shaping these views. While urban teachers are now skeptical about the pedagogical effectiveness of online-only models, rural teachers perceive them as fundamentally unviable due to insurmountable infrastructural barriers.

This study offers several crucial recommendations for the post-pandemic era, prioritized based on the urgency and foundational nature of the challenges identified:

A. Prioritized Recommendations:

- **Invest in Equitable Infrastructure:** National and regional governments must prioritize closing the digital divide by investing in reliable internet connectivity and ensuring device accessibility for all students, particularly in rural and remote areas. This is the most foundational step, as highlighted by rural teachers' experiences.
- **Develop Context-Aware Policies:** Future educational policies involving technology must account for regional disparities. Policymakers should consider developing flexible, hybrid models that allow schools in low-resource areas to adapt instruction to their local realities, rather than enforcing a one-size-fits-all approach.
- **Differentiated Professional Development:** Teacher training in educational technology must move beyond one-size-fits-all workshops. It should be context-specific, continuous, and focus on pedagogical strategies (TPACK) rather than just tool proficiency, catering to the nuanced needs of both urban and rural educators.

Ultimately, the lesson from the pandemic is not that online learning has failed, but that a system that ignores inequality is doomed to fail its students and teachers.

B. Limitations and Future Research:

This study, while offering rich qualitative insights, is limited by its small sample size of four EFL teachers from a specific region. The qualitative case study design provides in-depth understanding but limits generalizability to the broader Indonesian context. Additionally, the reliance on self-reported perceptions, though valuable, might be subject to recall bias.

For future research, it would be beneficial to:

- Conduct a larger-scale mixed-methods study to quantify the prevalence of these perceptions across more regions and validate qualitative findings.
- Explore student perceptions of online learning in both urban and rural settings to offer a complementary viewpoint.
- Investigate the long-term impact of ERT on teacher well-being and professional development trajectories, especially for those in under-resourced areas.
- Evaluate the effectiveness of specific hybrid learning models implemented in rural contexts post-pandemic.

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The Influence of Teachers' Communication Skills and the Learning Environment on Learning Motivation

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ABSTRACT

This study aims to analyze the influence of teachers' communication skills and the learning environment on students' learning motivation at SMK Swasta Poopo Bolmong. The research employed a quantitative approach with an ex post facto design, where the researcher did not provide direct treatment but examined the relationships among variables based on existing data. The sample was determined through proportional random sampling, and the research instrument was a Likert-scale questionnaire covering three main variables: teachers' communication skills, learning environment, and students' learning motivation. The results indicate that teachers' communication skills have a positive impact on students' learning motivation. Teachers who are able to deliver material clearly, coherently, and engagingly can enhance students' attention and interest in the learning process. Furthermore, a supportive learning environment, both physically and psychologically, plays an important role in encouraging students to be more enthusiastic and motivated in their studies. Simultaneously, teachers' communication skills and the learning environment complement each other in shaping students' learning motivation. This finding is consistent with learning motivation theory, which emphasizes that internal and external factors must interact synergistically for students to achieve optimal learning outcomes. The practical implication of this study is the need to improve teachers' communication skills and to develop a supportive learning environment so that students' learning motivation can grow sustainably.

Keywords: Teachers' Communication, Learning Environment, Learning Motivation

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1. INTRODUCTION

Education is one of the most important aspects in developing quality human resources. The educational process is not only oriented toward the transfer of knowledge, but also toward shaping attitudes, skills, and learning motivation of students. In this regard, the interaction between teachers and students becomes the core of an effective teaching and learning process. Teachers act not only as transmitters of knowledge, but also as facilitators, motivators, and communicators who are able to create a conducive learning atmosphere (Arum, S., 2019) (Astutik, F., & Wijayanti, 2020).

One of the essential skills that teachers must possess is communication ability. Good communication enables teachers to deliver material clearly, provide constructive feedback, and build positive interpersonal relationships with students. Teachers with strong communication skills tend to be able to motivate students to be more active in the learning process. Conversely, ineffective communication has the potential to cause boredom, misunderstandings, and even decrease students' learning motivation (Cesar Januarius et.al, 2024). In addition to teachers' communication skills, the learning environment also determines the success of learning. The learning environment includes the physical condition of the classroom, the availability of facilities, as well as the psychological and social atmosphere in the school. The organization and arrangement of the learning environment for individuals and students are greatly influenced by the surrounding environment. The emergence of good learning motivation among students is no exception, as it is driven by a learning environment that is conducive, enjoyable, and efficient in accordance with the characteristics and conditions of the students or individuals themselves (Nanang Abdul Jamal, et al, 2023).

Learning motivation itself is an internal factor that greatly determines students' academic achievement. Motivation encourages students to be more diligent, persistent, and strive to achieve optimal learning outcomes. Research shows that learning motivation is influenced by many factors, including teachers' communication skills and the learning environment. Students with high motivation are more prepared to face challenges, while those with low motivation tend to give up easily when facing difficulties (Pahriji Irgi Ahmad, 2021).

In the context of vocational high schools (SMK), learning motivation becomes even more important. SMK students are required not only to master academic aspects but also vocational skills that will be used in the workforce. Therefore, teachers in vocational schools must be able to establish effective communication with students and create a learning environment that supports both practical and theoretical learning processes. This condition is consistent with the findings of Jamal Nanang Abdul, et.al (2023), who found that a conducive learning environment significantly influences the learning motivation of vocational school students.

At SMK Swasta Poopo in Bolaang Mongondow Regency, the phenomenon of low learning motivation is still often found. Preliminary observations show that some students are less enthusiastic in attending lessons, less active in discussions, and often procrastinate in completing assignments. This is suspected to be influenced by teachers' communication skills that are not yet fully optimal and a learning environment that still requires improvement, both in terms of facilities and classroom climate. If this condition is not addressed, it will have an impact on the low quality of learning and students' learning outcomes.

This research is also supported by the findings of several previous studies. Suci (2020) showed that teachers' communication skills have a significant effect on increasing students' learning motivation in secondary schools. Furthermore, Nugroho & Putri (2021) emphasized that a conducive learning environment, both physically and psychologically, greatly contributes to the growth of students' motivation in vocational schools. Hakim (2022) also found that the combination of effective teacher communication and a supportive learning environment can optimally enhance learning motivation. Nevertheless, only a few studies have specifically examined the relationship between these two factors in the context of private vocational schools, particularly in Bolaang Mongondow Regency. Therefore, this research is important to fill the research gap and provide new empirical insights in the local context.

Based on these problems, research on *"The Influence of Teachers' Communication Skills and Learning Environment on Students' Learning Motivation at SMK Swasta Poopo Bolmong"* is very important to conduct. This study is expected to provide empirical insights into the extent to which these two factors affect students' learning motivation, as well as provide input for schools in improving the quality of the teaching and learning process. Thus, the findings of this research can serve as a basis for decision-making in designing more effective and innovative learning strategies.

The novelty of this research lies in its focus on examining the combined influence of teachers' communication skills and the learning environment on learning motivation specifically in private vocational schools within a rural/regional context such as Bolaang Mongondow Regency. Previous studies have mostly concentrated on general secondary schools or urban vocational schools, while research in rural private vocational schools is still limited. This study not only contributes to bridging the research gap in this specific educational setting but also provides practical insights that can be used by local schools and policymakers to design context-based strategies. Furthermore, this research emphasizes the dual role of teacher communication and learning environment simultaneously, offering a more holistic perspective compared to studies that analyzed these factors separately.

2. RESEARCH METHOD

This study employed a quantitative approach with an ex post facto research design, as the researcher did not directly manipulate the variables but examined causal relationships based on existing data. The quantitative approach was chosen because it allows the relationship between teachers' communication skills, the learning environment, and students' learning motivation to be described objectively and measurably (Hardani, et.al, 2020; Sugiyono, 2022). The population of the study consisted of all students at SMK Swasta Poopo in Bolaang Mongondow Regency. Using proportional random sampling, a total of 56 students were selected as the sample. In this technique, samples were drawn randomly from each class according to the proportion of students in that class. For instance, if a class represented 30% of the overall population, then approximately 30% of the sample was selected from that class. This procedure ensured that every student had an equal chance of being included, while maintaining balanced representation across different classes (Djaali, 2020).

The research instrument was a closed-ended questionnaire using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree), covering three main variables: (1) teachers' communication skills (15 items, e.g., *"The teacher explains the material clearly and understandably"*), (2) the learning environment (18 items, e.g., *"The classroom atmosphere supports me to concentrate during learning activities"*), and (3) students' learning motivation (20 items, e.g., *"I am motivated to study harder to achieve the best learning outcomes"*). Construct validity was initially assessed through expert judgment by two education experts to ensure the items accurately reflected the intended constructs. Empirical validity was then tested using Pearson's product-moment correlation, with all item-total correlations exceeding the critical r-value of 0.30. Furthermore, Exploratory Factor Analysis (EFA) was performed to examine factor loadings, followed by Confirmatory Factor Analysis (CFA) to confirm the dimensional structure of the instrument. All items demonstrated satisfactory loading on their respective constructs, indicating strong construct validity.

Reliability testing was conducted using Cronbach's Alpha. The results showed $\alpha = 0.872$ for teachers' communication skills, $\alpha = 0.884$ for the learning environment, and $\alpha = 0.902$ for students' learning motivation, confirming that all scales possessed high internal consistency (Ghozali, 2021). The collected data were analyzed using multiple linear regression to determine both the simultaneous and partial effects of teachers' communication skills and the learning environment on students' learning motivation. All analyses were conducted with the assistance of the latest version of SPSS statistical software (Santoso & Madiistriyatno, 2021)

3. RESULTS AND DISCUSSION

a. The Influence of Teachers' Communication Skills on Students' Learning Motivation at SMK Swasta Poopo Bolmong

Table 1. Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	11.164	3.941		2.833	.006
	Teachers' Communication Skills	.674	.099	.678	6.779	.000

a. Dependent Variable: Students' Learning Motivation

Explanation of the Results :

1) The regression output shows the influence of teachers' communication skills on students' learning motivation. The **constant value** is **11.164** with a significance value of **0.006** (< 0.05), meaning that even without the influence of teachers' communication skills, students' learning motivation already has a baseline score of 11.164.
2) The **unstandardized coefficient (B)** for teachers' communication skills is **0.674**, which means that for every one-unit increase in teachers' communication skills, students' learning motivation increases by **0.674 units**, assuming other factors remain constant.
3) The **standardized coefficient (Beta)** is **0.678**, indicating a strong and positive effect of teachers' communication skills on students' learning motivation. This value shows that teachers' communication skills are a dominant predictor compared to other potential variables.
4) The **t-value** is **6.779** with a significance value of **0.000** (< 0.05), which indicates that teachers' communication skills have a **significant positive effect** on students' learning motivation.

Table 2. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.678[a]	.460	.450	8.73831
a. Predictors: (Constant), Teachers' Communication Skills				

Explanation of the Results :

1) The correlation coefficient (R) is 0.678, which indicates a moderately strong positive relationship between teachers' communication skills and students' learning motivation. This means that as teachers' communication skills improve, students' learning motivation also tends to increase.
2) The coefficient of determination (R Square) is 0.460, which shows that 46% of the variance in students' learning motivation can be explained by teachers' communication skills. The remaining 54% is influenced by other factors not included in the model.
3) The Adjusted R Square value is 0.450, which adjusts the R^2 to account for the number of predictors in the model. This value confirms that the model still explains around 45% of the variation in students' learning motivation, indicating a good level of explanatory power for a single predictor.
4) The Standard Error of the Estimate (SEE) is 8.73831, reflecting the average distance that the observed values fall from the regression line. A lower SEE indicates a better fit of the model, and in this case, the value shows a reasonably acceptable fit for educational research.

b. The Influence of the Learning Environment on Students' Learning Motivation at SMK Swasta Poopo Bolmong

Table 3. Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	11.519	3.866		2.980	.004
	Learning Environment	.745	.109	.681	6.825	.000
a. Dependent Variable: Students' Learning Motivation						

Explanation of the Results :

1) The constant (intercept) is 11.519, with a t-value of 2.980 and p-value (Sig.) = 0.004. This means that if the learning environment factor were absent (score = 0), students' learning motivation would still have a baseline value of 11.519. The result is statistically significant because the p-value is less than 0.05.
2) The unstandardized coefficient (B) for the learning environment is 0.745, with a standard error of 0.109. This indicates that for every 1-unit increase in the learning environment score, students' learning motivation increases by 0.745 units, assuming all other variables are held constant.
3) The standardized coefficient (Beta) is 0.681, which means the learning environment has a strong positive effect on students' learning motivation compared to other possible predictors. A Beta value close to 1 shows a substantial contribution.
4) The t-value for the learning environment is 6.825, with a p-value (Sig.) = 0.000, which is far below the 0.05 threshold. This confirms that the effect of the learning environment on students' learning motivation is highly significant.

Table 4. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.681[a]	.463	.453	8.71129
a. Predictors: (Constant), Learning Environment				

Explanation of the Results:

1) The correlation coefficient (R) is 0.681, which indicates a strong positive relationship between the learning environment and students' learning motivation. This suggests that as the quality of the learning environment improves, students' motivation to learn also increases.
2) The coefficient of determination (R Square) is 0.463, meaning that 46.3% of the variance in students' learning motivation can be explained by the learning environment. The remaining 53.7% is influenced by other factors not included in the model.
3) The adjusted R Square value is 0.453, which accounts for the sample size and number of predictors in the model. This adjusted value shows that the model still explains around 45.3% of the variance in learning motivation after adjustments, confirming the stability of the result.
4) The standard error of the estimate is 8.71129, which represents the average distance between the observed values and the regression line. A lower standard error would indicate more accurate predictions, and in this case, the error is still within an acceptable range for educational research.

c. The Influence of Teachers' Communication Skills and the Learning Environment on Students' Learning Motivation at SMK Swasta Poopo Bolmong

Table 5. Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	8.655	3.935		2.199	.032
	Teachers' Communication Skills	.367	.162	.369	2.264	.028
	Learning Environment	.418	.179	.382	2.342	.023

a. Dependent Variable: Learning Environment

Explanation of the Results :

1) Constant (8.655; p = 0.032)
   The constant value indicates that if both independent variables (teachers' communication skills and the learning environment) are assumed to be zero, the students' learning motivation remains at 8.655. This represents the baseline level of motivation before being influenced by the independent variables.
2) Teachers' Communication Skills (B = 0.367; Beta = 0.369; p = 0.028)
   a. The regression coefficient of 0.367 means that for every one-unit increase in teachers' communication skills, students' learning motivation will increase by 0.367 points, assuming other variables remain constant.
   b. The Beta value of 0.369 shows the relative contribution of teachers' communication skills, which is 36.9%.
   c. Since the significance value is 0.028 (< 0.05), teachers' communication skills have a significant positive effect on students' learning motivation.
3) Learning Environment (B = 0.418; Beta = 0.382; p = 0.023)
   a. The regression coefficient of 0.418 indicates that for every one-unit improvement in the learning environment, students' motivation will increase by 0.418 points, assuming other variables remain constant.
   b. The Beta value of 0.382 reflects a relative contribution of 38.2%, which is slightly higher than that of teachers' communication skills.
   c. With a significance value of 0.023 (< 0.05), the learning environment also has a significant positive influence on students' learning motivation**.**

Table 6. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate

1	.714[a]	.510	.492	8.39657
a. Predictors: (Constant), Teachers' Communication Skills and the Learning Environment				

Explanation of the Results :
1) R = 0.714
   This value shows a strong positive correlation between the predictors (teachers' communication skills and the learning environment) and students' learning motivation. A value closer to 1 indicates a stronger relationship.
2) R Square = 0.510
   The coefficient of determination shows that 51% of the variance in students' learning motivation can be explained by teachers' communication skills and the learning environment combined. The remaining 49% is influenced by other factors not included in the model, such as parental support, peer influence, self-efficacy, or intrinsic interest.
3) Adjusted R Square = 0.492
   This value adjusts R^2 for the number of predictors and sample size. At 49.2%, it confirms that the model is reliable and not overly inflated by chance.
4) Std. Error of the Estimate = 8.39657
   This represents the average distance between the observed values and the regression line. A smaller standard error indicates more accurate predictions. With this value, the model has an acceptable level of prediction accuracy for students' learning motivation.

d. The Influence of Teachers' Communication Skills on Students' Learning Motivation

The results of the study show that teachers' communication skills have a positive and significant influence on students' learning motivation at SMK Swasta Poopo Bolmong. The regression test data indicate a positive coefficient value with a significance level below 0.05, which means that teacher communication is an important factor in fostering learning motivation. Teachers who are able to deliver material clearly, systematically, and in an easily understandable manner help students stay focused and maintain interest throughout the learning process. Conversely, ineffective communication can lead to confusion, boredom, and even a decline in students' learning motivation.

From a theoretical perspective, these findings are consistent with the view of Desi Ratna Sari (2024), who emphasizes that teacher communication is the main medium for connecting knowledge with learners. Communication is not merely about delivering messages but also involves listening skills, providing constructive feedback, and fostering a healthy dialogical climate in the classroom. According to educational communication theory, teachers must act as effective communicators so that learning messages can be optimally received by students.

Previous research also supports this finding. Didit Darmawan et.al. (2021), in their study, found that teacher communication significantly affects the improvement of learning motivation among secondary school students. Teachers with interpersonal communication skills are able to foster students' self-confidence, build emotional closeness, and develop sustainable learning interest. This indicates that effective communication is not only technical in nature but also emotional and psychological.

Nur Laily Nafi'aini (2025) revealed that teacher communication that is clear, empathetic, and open can create an enjoyable learning atmosphere, motivating students to be more active. In the context of vocational education such as SMK, communication that is practical, relevant to the world of work, and delivered in a language appropriate to students' level of understanding further enhances their learning motivation. This is because students feel that the material presented has direct value and benefits in everyday life as well as in future employment.

The results of this study confirm that teacher communication is one of the key variables in improving students' learning motivation. A teacher's ability to communicate effectively can serve as a bridge that connects the cognitive, affective, and psychomotor aspects of learning. Therefore, teachers are expected to continuously develop their communication skills, both verbal and nonverbal, to foster students' learning motivation in a sustainable way.

e. The Influence of Learning Environment on Students' Learning Motivation

The results of this study also show that the learning environment has a positive and significant influence on students' learning motivation. A positive regression coefficient with a significance level

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of < 0.05 indicates that the more conducive the learning environment created, the higher the level of learning motivation experienced by students. The learning environment includes physical factors, such as the availability of facilities and infrastructure, comfortable classrooms, and supporting technology, as well as non-physical factors, such as the social climate, student relationships, and the psychological atmosphere in the classroom.

Constructivist theory, as proposed by Piaget and Vygotsky, explains that the learning environment plays an important role in helping students build meaningful learning experiences (Santrock, 2020). A safe, comfortable, and supportive environment allows students to be more focused in the learning process. Conversely, an unconducive environment can trigger distractions, boredom, and even reluctance to learn. Therefore, teachers and schools must be able to create a conducive environment so that learning motivation can develop effectively.

The study by Ahmad Juaini, et.,al (2024) reinforces these findings by showing that a conducive learning environment, both physically and psychologically, plays a significant role in enhancing the learning motivation of vocational high school students. Their research highlights the importance of classroom arrangement, utilization of facilities, and the creation of harmonious interaction to improve students' enthusiasm for learning. A pleasant environment can foster a sense of comfort and eagerness in attending lessons.

Furthermore, Fahriji (2021), revealed that adequate learning facilities and a positive social climate in schools make a major contribution to students' learning motivation. Facilities such as laboratories, libraries, and access to technology can become driving factors for motivation because students feel they are maximally supported by the school. This indicates that a good learning environment not only supports learning technically but also increases students' internal drive to achieve (Mes et al., 2022).

The findings of this study further emphasize that the learning environment is an external factor that cannot be ignored in improving learning motivation. Schools that aim to improve the quality of education must pay attention to environmental aspects, both physical and non-physical. A conducive environment creates an enjoyable learning atmosphere, encouraging students to be more enthusiastic, motivated, and ready to participate actively in the learning process.

f. The Influence of Teachers' Communication Skills and Learning Environment on Students' Learning Motivation

Teachers' communication skills are one of the important factors influencing students' learning motivation. Teachers who are able to deliver subject matter clearly, systematically, and engagingly can foster students' interest in learning and increase their active involvement in the learning process. Good communication not only includes delivering information but also the ability of teachers to listen, provide feedback, and build positive interactions with students. Thus, students feel noticed, valued, and supported in achieving their learning goals. This aligns with the view that effective communication can strengthen the emotional bond between teachers and students, thereby creating a conducive learning atmosphere.

In addition to teachers' communication skills, the learning environment also plays a crucial role in shaping students' learning motivation. A comfortable, well-organized learning environment equipped with adequate facilities can enhance students' focus and interest in participating in learning activities. Physical environmental factors such as lighting, cleanliness, and the availability of learning media, as well as social environmental factors such as relationships among students and a harmonious classroom climate, contribute significantly to learning success. A supportive environment will make students feel at ease, motivated, and have a stronger internal drive to achieve.

The interaction between teachers' communication skills and the learning environment shows a complementary influence. Communicative teachers will find it easier to create a positive classroom climate, while a conducive learning environment will strengthen the effectiveness of teachers' communication in delivering lessons. In other words, teachers' communication skills and the learning environment not only influence students' motivation partially but also simultaneously. Students who are in a supportive learning environment and guided by teachers with good communication skills tend to demonstrate higher levels of motivation compared to those who do not receive both supports.

Based on this explanation, it can be understood that increasing students' learning motivation cannot be separated from teachers' efforts to improve their communication skills along with providing an optimal learning environment. Therefore, schools and related parties need to pay attention to the development of teachers' communication competence through training, workshops, or coaching, as well as ensure that the learning environment at school meets comfort and feasibility standards. With the synergy between personal factors (teachers' communication skills) and external factors (learning environment), students' learning motivation will increase and ultimately have a positive impact on learning achievement.

4. CONCLUSION

Based on the results of the study, it can be concluded that teachers' communication skills have a positive influence on students' learning motivation. Teachers who are able to deliver material clearly, coherently, and engagingly can enhance students' attention, interest, and active participation in the learning process. This shows that effective communication is one of the key factors in creating a meaningful learning atmosphere. In addition, the learning environment also plays a significant role in increasing students' learning motivation. A conducive environment, both physically and psychologically, provides comfort, a sense of security, and encouragement for students to be more diligent in participating in learning activities. Thus, external factors in the form of learning conditions cannot be ignored in efforts to improve students' learning quality.

Simultaneously, teachers' communication skills and the learning environment complement each other in shaping students' learning motivation. Both work synergistically to create an interactive, supportive, and enjoyable learning situation. This aligns with learning motivation theories that emphasize the importance of interaction between internal and external factors for students to achieve optimal learning outcomes.

The practical implication of this research is the need to improve teachers' communication skills through training, workshops, and reflective practice so that they can deliver material more effectively and build positive relationships with students. In addition, schools need to pay attention to the development of supportive learning environments, both by providing adequate facilities and creating a harmonious classroom climate.

Therefore, efforts to improve students' learning motivation cannot rely on a single factor, but must be carried out in an integrated manner between enhancing teachers' communication quality and providing a conducive learning environment. If both aspects are well addressed, students' learning motivation will develop sustainably and have a positive impact on learning achievement.

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Application of Fuzzy Time Series Chen and Cheng Methods to Forecast Profit in a State-Owned Insurance Company

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ABSTRACT

PT. Taspen (Persero) as a state-owned enterprise in the services sector needs to analyze financial performance to understand the fluctuations in quarterly profit in 2022. This study aims to compare the accuracy level of the Fuzzy Time Series Chen and Fuzzy Time Series Cheng methods in predicting the profit of PT Taspen (Persero) in the period May 2023 to July 2024. The data used is monthly actual profit data that shows a fluctuating pattern with the highest peak in December 2023. The forecasting results using the Chen method show a more stable prediction pattern and tend to experience overestimation in some periods, such as November 2023 and May 2024. Meanwhile, Cheng's method produces a forecast pattern that is closer to actual data, although there is an unrealistic spike in February 2024. Based on the results of forecasting accuracy measurement, Cheng's method has a MAPE value of 0.603, MSE of 2.684, and MAE of 1,172.53, while Chen's method has a MAPE value of 0.674, MSE of 3.303, and MAE of 1,319.29. These values show that Cheng's method has a higher level of accuracy than Chen's, so it can be recommended as a more reliable method for projecting PT Taspen (Persero's profit).
Keywords: PT. Taspen (Persero), Fuzzy Time Series Chen, Fuzzy Time Series Cheng, Profit Prediction.

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1. INTRODUCTION

A business generally has the same goal, which is to impede the profit that is made as a measure of the success of a business in carrying out its activities. Profit is the amount of income from sales that has been followed by the business, and also to measure the performance of the business (Eirmaya eit al., 2016). Measuring the performance of a company, one of which can be used in insurance companies. One The insurance company in Indonesia is PT. Taspen (Persero) is a state-owned enterprise that is a subsidiary of insurance for old age savings and investment for ASN as well as a government official.

Because profit data fluctuates in certain periods, this can affect the performance of PT Taspen (Persero). So, it is necessary to carry out a forecast that will function to know the prospects of PT Taspen (Persero) and be able to predict the dividends that will be received in the future. Forecasting can help the company's ability to continue to develop its business in assessing management performance, help estimate representative profit ability in the long term, and can assess risks in investing or credit (Admirani, 2018).

Forecasting is a technique to make a value in the future by paying attention to past data and current data. The quantitative forecasting method is divided into two types of models, namely the regression model and the time series model (Aswi & Sukarna, 2006). One of the time series forecasting methods is Fuzzy Time Series (FTS). Fuzzy Time Series uses the concept of fuzzy in forecasting, data relationships, and time intervals to form fuzzy relationships. The determination of intervals has an effect on the difference in forecasting. The Fuzzy Time Series method is a forecasting method introduced by Song and Chissom (1993) using the concept of fuzzy; fuzzy logic, fuzzy sets, and linguistic variables. Vague data is explained with linguistic values (Habinuddin, 2022). Many Fuzzy Time Series methods have been developed, including the Fuzzy Time Series Chen method, and the Fuzzy Time Series Cheng method (Kusumadewi and Purnomo, 2013).

The advantage of Chen's Fuzzy Time Series method is that it uses a basic approach that is easy to understand and apply, without requiring a deep understanding of fuzzy logic. This simplicity allows for faster and 3rd efficient implementation in a wide range of prediction applications (Chen, 1996). Meanwhile, the advantage of Fuzzy Time Series Cheng is that it provides more accurate prediction results, especially for time series data with more complex patterns. Cheng used more sophisticated fuzzy interval determination, which allowed the model to capture more information from the data (Arnita et al., 2020).

The stages of the Fuzzy Time Series Chen and Fuzzy Time Series Cheng methods are illustrated in figure 1.

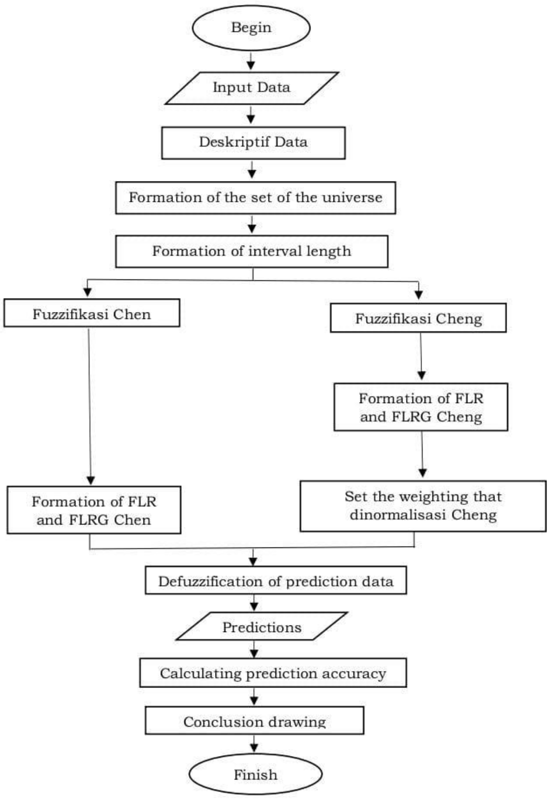

Figure 1. Illustrated method Fuzzy Time Series Chen and Fuzzy Time Series Cheng

Research using *Fuzzy Time Series* has been widely used, as has been researched by Pambudi et.al., (2018) to predict the number of fire spots as an identification of fire. The test was carried out to determine the accuracy of the prediction of the number of fire occurrences over the monthly and 10-day period.

The study by Sugumonrong et al., (2019) with gold price data for the period January 1, 2015 to December 31, 2017, obtained prediction results using *the Fuzzy Time Series method* where the average difference between the actual data and prediction data is no more than Rp. 2,850,- where the prediction uses *the fuzzy Time Series* method of *the Chen* algorithmIt is enough to use 1 data to predict the 2nd data which makes this method can be said to be accurate in predicting the price of gold.

In the study conducted by Arvie (2022), one of the methods to make predictions or forecasts was used, namely *the Fuzzy Time Series Cheng method*. The actual data used is Oil and Gas and Non-oil and Gas Import Forecasting from January 2019 to October 2021, and an import prediction process will be carried out from November 2021 to August 2024. Based on the results of the calculations that have been carried out using *Cheng's Fuzzy Time Series method*, a performance conclusion is produced that is said to be very good.

In this study, Chen's Fuzzy Time Series and Cheng's Fuzzy Time Series methods were used because they both offer different approaches to handling data. The chen method is known to be efficient and simple for data with stable patterns, while the cheng method has the advantage of handling more complex data through adaptive fuzzy interval determination. By comparing these two methods, the study aims to find out which method is the most accurate in predicting profits.

Based on this background, this study was conducted to apply the Fuzzy Time Series Chen and Fuzzy Time Series Cheng methods in predicting the profit of PT. Taspen (Persero), and compared the accuracy level of the two methods with the title **"The Use of the Fuzzy Time Series Chen and Fuzzy Time Series Cheng Methods to Predict Profit at PT. Taspen (Persero)".**

2. RESEARCH METHOD

2.1 Fuzzy Time Series Chen

Chen (1996) developed the Fuzzy Time Series based on Song and Chissom (1993) with simple operations, the development of the Fuzzy Time Series method has complex matrix operations, and has a very large influence on the Fuzzy Time Series method, there are various models, namely the Song, Chissom, Chen and Lee models. The Fuzzy Time Series process of interval length will be determined first because the length of the interval will affect the prediction results, so the formation of a fuzzy relationship (FLR) will be appropriate.

The initial step in Fuzzy Time Series analysis is the formation of a universal set (U). In forming a universal set (U), the smallest (minimum) and largest (maximum) data from PT Taspen's profit data are required.Below will be explained the steps of the Fuzzy Time Series method using the Chen Algorithm:

Step 1. The formation of the set of the universe (U).

$$U = [D_{min} - D_1 \; ; \; D_{max} + D_2] \quad (1)$$

With

D_1 dan D_2 : Any number of positives
D_{min} : Smallest data from historical data
D_{max} : The largest data of historical data

Step 2. Interval formation

Dividing the set of the universe into intervals of equal distance. To find out the many intervals, you can use the Sturges formula as follows: (2)

$$K = 1 + 3{,}322\log(n)$$

With,
n : amount of historical data (observations)

After the number of intervals is obtained, then determine the length of the interval using the following formula. (3)

$$I = \frac{D_{max} - D_{min}}{Jumlah\ Interval}$$

So that it forms a number of linguistic values to represent a fuzzy set at intervals formed from the set of the universe (U). (4)

$$U = \{u_1, u_2, \dots, u_i\}$$

U : From the semen of Himpuna
u_i : the magnitude of the interval in , for $Ui = 1, 2, \dots, p$

Step 3. Define a *fuzzy* set

A fuzzy set is a class or group of objects with a continum of the degree of membership. Suppose U is a set of universes, with U={$u1$,$u2$,…,ui}where ui is the possible value of U, then the linguistic variable Ai with respect to U can be formulated as follows.

$$A_i = \frac{\mu A_i(u_1)}{u_1} + \frac{\mu A_i(u_2)}{u_2} + \dots + \frac{\mu A_i(u_k)}{u_k} \quad (5)$$

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The fuzzy set Ai has a membership function, namely μAi, so that $\mu A_i : U \rightarrow [0,1]$.If ,u-i. is a member of Ai, then $\mu A_i(u_i)$ is the degree of membership , u_i. to Ai (Brata, 2016).
The results of the membership degree are obtained from the following rules.

1. If the historical data of , F_t is included in , u_i then the value of the degree of membership for , u_i is 1, and , u_{i+1} is 0.5 and if it is not , u_i and , u_{i+1}it is declared zero.
2. If the historical data of , F_t. is included in , u_i, $1 \leq i \leq n$ then the value of the degree of membership for u_i. is 1, for u_{i-1} and , u_{i+1} is 0.5 and if it is not u_i, u_{i-1} and , u_{i+1} it is declared zero.
3. If the historical data of , F_t is included in , u_i., then the value of the degree of membership for , u_i. is 1, and , u_{i-1}. is 0.5 and if it is not , u_i. and , u_{i-1}. it is declared zero.

Step 4. Fuzzification of historical data
This stage determines the membership value of each fuzzy set of historical data. The input data is received and the system determines the value of its membership function and converts numerical variables (non-fuzzy variables) into linguistic variables (fuzzy variables). In other words, fuzzification is the grouping of numerical numbers in the corresponding fuzzy set. The membership function gives meaning or defines linguistic expressions into numbers that can be manipulated. Fuzzification obtains a value and combines it with membership functions to generate a fuzzy value. Fuzzification is the process of determining an input number for each fuzzy group.

Step 5. Defining *Fuzzy Logic Relations* (FLR)
Define FLR and create groups according to time. In the fuzzified data, 2 consecutive fuzzy sets A_i or fuzzy sets at time , $(t-1)$. and , A_j. fuzzy sets at time t can be expressed as FLR or relations , $A_i \rightarrow A_j$. Next is the formation of FLRG using FLR which has LHS (Left Hand Side) or FLR with fuzzy set which has the same $(t-1)$. For example, if FLR is formed from $A_1 \rightarrow A_2, A_1 \rightarrow A_1, A_1 \rightarrow A_3, A_1 \rightarrow A_1$then FLRG is formed, namely $A_1 \rightarrow A_1, A_2, A_3$.

Step 6. Defining Fuzzy Logic Relations Group (FLRG)
Next is the formation of FLRG using FLR which has LHS (Left Hand Side) or FLR with a fuzzy set that has the same , $(t-1)$. For example, if FLR is formed from $A_1 \rightarrow A_2, A_1 \rightarrow A_1, A_1 \rightarrow A_3, A_1 \rightarrow A_1$, then FLRG is formed, namely $A_1 \rightarrow A_1, A_2, A_3$

Step 7. Forecasting and Defuzzification
Suppose $F_t \rightarrow A_1, A_2, A_t$ then the equation to find the final forecast value is as follows.

$$\widehat{F_t} = \frac{\sum_{i=1}^{k} m_i}{k} \quad (6)$$

With

$\widehat{F_t}$: deifuzziifiication
m_i : the middle value of A_i

Defuzzification of the value of the previous data, F-t. is Chen's Fuzzy Time Series method which has several rules that must be observed to make a forecast. The following are the rules:

1. If the fuzzification value of data to t is , A_j then there is a fuzzy set that has no fuzzy logical relationship, such as , $A_j \rightarrow \emptyset$, whose maximum value of the membership function of , A_f. is at the interval , u_i., then the middle value , u_i. is , m_i. so that it can be seen that the result of the forecast , F_{t-1}. is m_i.
2. If the fuzzification value of the data to t is A_i. where there is only one FLR in the FLRG, such as , $A_i \rightarrow A_j$. with A_i. and , A_j. is a fuzzy set whose maximum value is the membership function of A_j. is at the interval u_j, then the middle value of u_j. is u_j., so that the forecast result F_{t-1}. is m_j.

3. When the fuzzification values of the data to t are A_i and A_j. have multiple FLRs and FLRGs, such $A_1 \rightarrow A_{j1}, A_{j2}, \dots, A_{jk}$, with $A_{j1}, A_{j2}, \dots, A_{jk}$. is a fuzzy set then the maximum value of the membership function of $A_{j1}, A_{j2}, \dots, A_{jk}$ is at the intervals $u_{j1}, u_{j2}, \dots, u_{jk}$ and $m_{j1}, m_{j2}, \dots, m_{jk}$, so that the result of the forecast is F_{t-1} as follows:

$$F_t = \frac{m_{j1}, m_{j2}, \dots, m_{jk}}{k} \quad (7)$$

With,
k : the number of middle values

To find the middle value (m_i) in the interval of the fuzzy set, the following equation can be used:

$$m_i = \frac{upper\ limit + lower\ limit}{2} \quad (8)$$

2.2 Fuzzy Time Series Cheng

Cheng's method has a slightly different way of determining intervals, using FLR by including all relationships and giving weights based on the same sequence and looping of FLRs (Tauryawati & Irawan, 2014). The following are the stages of forecasting time series data using FTS Cheng:

Step 1. The formation of a set of universes (U).

$$U = [D_{min}, D_{max}] \quad (9)$$

with,
D_{min} : Smallest data from historical data
D_{max} : The largest data of historical data

Step 2. Interval formation

Using frequency distribution, with the following steps:
Define the range.

$$R = D_{max} - D_{min} \quad (10)$$

with,
R : range

Determine the number of class intervals using the sturges equation.

$$K = 1 + 3{,}322 \log(n) \quad (11)$$

Specify the width of the interval.

$$I = \frac{Range\ data(R)}{number\ of\ \ intervals} \quad (12)$$

Find the middle value

$$m_i = \frac{lower\ limit + upper\ limit}{2} \quad (13)$$

with
i : Lots of *fuzzy* sets

Step 3. Defining *Fuzzy* Sets

A fuzzy set is formed by looking at the number of different frequencies, then at the first most frequency it is divided into h intervals of the same time. Next, the second most frequency is divided over $i-1$of the same interval, the interval at the third most frequency is divided into $i-2$ of the same interval. This is done up to intervals with undivided frequencies.

Step 4. Fuzzification of Historical Data

Define the fuzzy set A_i. and perform fuzzification on the actual observed data. Suppose $A_1, A_2, \dots, A_p$ is a fuzzy set that has the linguistic value of a linguistic variable, the definition of the fuzzy set $A_1, A_2, \dots, A_p$ in U is as follows:

$$\begin{aligned} A_1 &= \frac{1}{u_1} + \frac{0,5}{u_2} + \frac{0}{u_3} + \dots + \frac{0}{u_p} \\ A_2 &= \frac{0,5}{u_1} + \frac{1}{u_2} + \frac{0,5}{u_3} + \dots + \frac{0}{u_p} \\ A_3 &= \frac{0}{u_1} + \frac{0,5}{u_2} + \frac{1}{u_3} + \dots + \frac{0}{u_p} \\ &\vdots \\ A_p &= \frac{0}{u_1} + \frac{0}{u_2} + \frac{0}{u_3} + \dots + \frac{0,5}{u_{p-1}} + \frac{1}{u_p} \end{aligned} \tag{14}$$

with, $u_i (i = 1,2, \dots, p)$ is an element of the set of the universe $(U)$and a number marked with the symbol "/" which expresses the degree of membership of $\mu_{A_i}(u_i)$ against A_i $(i = 1,2, \dots, p)$where the value is $0, 0{,}5$ atau 1.

Step 5. Define and create a Fuzzy Logic Relations (FLR) table

FLR can be denoted by $A_i \rightarrow A_j$ where $A_i$is called the *current state* and A_j is called the *next state*.

Step 6. Determining the weight of FLR relations into a Fuzzy Logic Relations Group (FLRG)

Enter all relationships and give weights based on the same order and loop. FLRs that have the same *current state* (A_i) are combined into a single group into the form of a weighting matrix. Suppose there is a sequence of the same FLR

$(t = 1)$ $A_1 \rightarrow A_1$, given weight 1

$(t = 2)$ $A_2 \rightarrow A_1$, given weight 1

$(t = 3)$ $A_1 \rightarrow A_1$, given a weight of 2

$(t = 4)$ $A_1 \rightarrow A_1$, given a weight of 3

With,
t : time.

Then the weights obtained in the FLR relation are entered into the form of a weighting matrix (W) whose equation is written as follows:

$$W = \begin{bmatrix} w_{11} & w_{12} & \dots & w_{1p} \\ w_{21} & w_{22} & \dots & w_{2p} \\ \vdots & \vdots & w_i & \vdots \\ w_{p1} & w_{P2} & \dots & w_p \end{bmatrix} \tag{15}$$

with,
W : weighting matrix
w_i : matrix weights in the first row and the -i column -j with i $i = 1,2, \dots, p$; $j = 1,2, \dots, p$

Step 7. Transfer the FLRG weight into the form of a standardized weighting matrix (W^*)

The equation is written as follows:

$$W^* = \begin{bmatrix} w_{11}^* & w_{12}^* & \dots & w_{1p}^* \\ w_{21}^* & w_{22}^* & \dots & w_{21}^* \\ \vdots & \vdots & w_i & \vdots \\ w_{p1}^* & w_{p2}^* & \dots & w_{pp}^* \end{bmatrix} \quad (16)$$

with,

W^* : Standardized weighting matrix with $w_i^* = \frac{w_i}{\sum_{j=1}^{p} w_i}$

Step 8. Determining the forecasting value specification

To generate the forecast value, the standardized weighting matrix $(W^*)$is multiplied by (m_i). Finding the middle value (m_i) at the interval of a fuzzy set can use Equation (5). So that the calculation of the prediction becomes:

$$F_i = w_{i1}^* \,(m_1) + w_{i2}^* \,(m_2) + \cdots + w_{ip}^* (m_p) \quad (17)$$

with,

F_i : Forecast results

If the fuzzification value of the -i period is -A_i. and A_i. does not have FLR in the FLRG with the condition $A_i \to \emptyset$, where the maximum value of the degree of membership is in the interval u_i., then the forecast value (F_i) is the middle value of the interval u_i., or defined by m_i.

2.3 Forecasting Accuracy

Forecasting is the goal of time series analysis. The forecasting method has the goal of getting optimal forecast results without having a large error rate. If the error rate that has been obtained is smaller, the result of a forecast will be closer to the actual value (Wei, 2006). In this study, the accuracy of the forecast will be calculated using *Mean Absolute Percentage Error* (MAPE), *Mean Squared Error* (MSE), and *Mean Absolute Error* (MAE).

1. *Mean Absolute Percentage Error* (MAPE)

MAPE is the average of the overall percentage of error (difference) between actual data and predictive data (Sukerti, 2015). Systematically MAPE is shown as follows (Makridakis, eit al., 1999).

$$MAPE = \frac{100\%}{n} \sum_{t=1}^{n} \left| \frac{F_t - \hat{F}_t}{F_t} \right| \quad (18)$$

with,

n : Lots of data

F_t : Observation data at time t

$\hat{F}_t$: data of forecasting results at time t

The interpretation of the MAPE value is shown in the following table (Lewis, 1982).

Table 1. Interpretation of MAPE Values

MAPE (%)	Interpretasi
< 10	Highly Accurate Predictions
$10 - 20$	Good predictions
$20 - 50$	Decent predictions
> 50	Inaccurate predictions

2. *Mean Squared Error* (MSE)

MSE is a calculation used in measuring the average of the squares obtained between the difference between the expected value and the output value of the prediction. The lower the value obtained from the MSE calculation, the more accurate the prediction results will be considered (Wiranto, Setiawan, Nuryaman, & Usman, 2003). Systematically MSE is shown as follows (Makridakis et.al, 1982).

$$MSE = \frac{\sum(Yi - \hat{Y}i)^2}{n} \tag{19}$$

With,
n : Lots of data
Y_i : Actual value of data i
$\hat{Y}_i$: Predictive value of data i

3.*Mean Absolute Error* (MAE)
MAE is one of the methods used to measure the accuracy of forecasting models. The MAE value shows the absolute average error between the forecast/prediction results and the real value (Subagyo, 1986). In terms of the MAE formula, it is explained as follows.

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|F_i - Y_i| \tag{20}$$

With,
n *: Lots of data*
F_i *: The value of the application results to i i*
Y_i *: the actual value to i*

3. RESULTS AND DISCUSSION

A. PT Taspen's Profit Forecasting Using *Fuzzy Time Series Chen*

The steps for forecasting PT Taspen's profit using the Fuzzy Time Series Chem method are as follows:

Step 1. Determine the set of the universe (*U*) from historical data.

The initial step of Fuzzy Time Series analysis is the formation of a set of universes (*U*). In the formation of the universe set (*U*), it requires the smallest (minimum) data and the largest data (maximum) from PT Taspen's profit data. Minimum profit value in the month (D_{min}) January 2024, which is Rp. 2.451.700.000 while the maximum profit value in December 2023 is (D_{max}) IDR 106.516.180.000. In this study, the author determined the value for *D1 to be 0.17 and the value for D2 was 0.22.* Furthermore, after obtaining the values and determining the values $D_{min}D_{max}$ *of D1 and D2, the next step is to form a set of universes (U*) as in equation (1). The following is the set of the universe (*U*) that is formed.

$$\begin{aligned} U &= [D_{min} - D_1 \,; D_{max} + D_2] \\ &= [2.451.700.000 - 0{,}17 \,; 106.516.180.000 + 0{,}22] \\ &= [2.451.530.000; 106.516.400.000] \end{aligned}$$

Step 2. Determining the number of intervals (m)

The next step is to determine the number of intervals or the number of interval classes of the entire set of the universe (U) using the following equation (2).

$$\begin{aligned} K &= 1 + 3{,}322 \log(15) \\ &= 1 + 3{,}907 \\ &= 4{,}907 \approx 5 \end{aligned}$$

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Based on these results, 5,001 is obtained for the number of intervals rounded up to 5 intervals. Then the set of the universe (*U*) will be partitioned into 5 intervals into $u_1, u_2, u_3, \ldots, u_5$. by searching the Length of each interval using the following equation (3):

$$I = \frac{D_{max} - D_{min}}{K}$$

$$= \frac{106.516{,}18 - 2.451{,}70}{5}$$

$$= 20.812.896.000$$

The results of the 5 intervals formed and the middle values in each of these intervals are presented in the following table:

Table 2. Interval of Universe Aggregate (U) Profit of PT Taspen (Persero)

Intervals (u_i)	**Middle value** (m_i)
$u_1 = [2.451.530.000; 23.264{,}426]$	$\mathbf{12.857.978.000}$
$u_2 = [23.264.426.000; 44.077.322.000]$	$\mathbf{33.670.874.000}$
$u_3 = [44.077.322.000; 64.890.218.000]$	$\mathbf{54.483.770.000}$
$u_4 = [64.890.218.000; 85.703.144.000]$	$\mathbf{75.296.681.000}$
$u_5 = [85.703.144.000; 106.516.010.000]$	$\mathbf{96.109.577.000}$

Step 3. Identifying *Fuzzy sets*

The *range of fuzzy* sets is used to derive the value of each *fuzzy set* that is formed. The minimum value is that it will have a membership degree of 1 and be a value of . (D_{min})2.451.700.000 A_1. This is because the value is defined in the association so that it has a membership degree of 1. 2.451.700.000 $u_1 fuzzy\ A_1$. Then the value is A_1 added with the value of the fuzzy range so that a value of A_2 that is 28.467.820.000. By applying the same step, the value of which is the maximum value will be obtained, namely $A_5(D_{max})$106.516.180.000 With Membership Degree of 1. The values of the fuzzy set will form the membership degree curve that is used to find the membership value of each data in the *fuzzy* set. The curve of the membership value formed can be seen in the following figure:

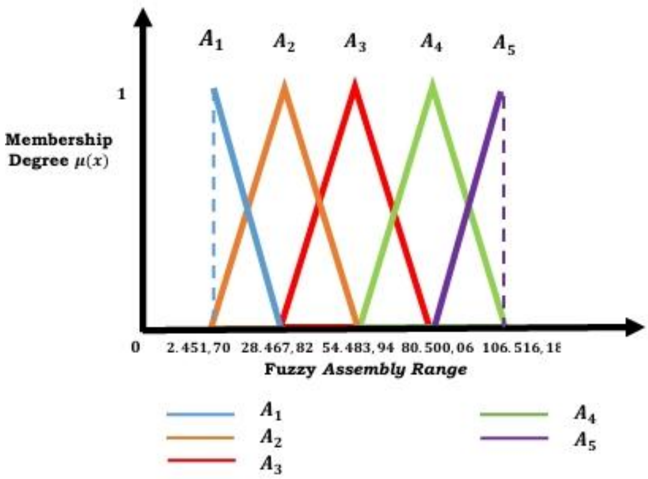

Figure 2. Fuzzy Profit Association of PT Taspen (Persero)

Figure 1 above shows that the membership degree curve of the formed fuzzy set values is a representation of the triangle curve. In this study, the linguistic value represented is

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$A_1, A_2, A_3, \dots, A_5$ on top of which each has a range of profit values. Suppose is a linguistic value that represents the range of profit values of $A_1$2.451.700.000 until. 28.467.820.000. Then, is the linguistic value A_2 which represents the range of profit values from 28.467.820.000 until 54.483.940.000 and so on.

Step 4. Determine the membership of each data
The calculation of the membership value of each data refers to the curve formed in Figure 12. For example, for the calculation of the value of the degree of membership, the first profit data of PT Taspen (Persero), namely April 2022 data, is $x = 16.837.410.000$ When the value of $x = 16.837.410.000$ be on the following triangular curve:

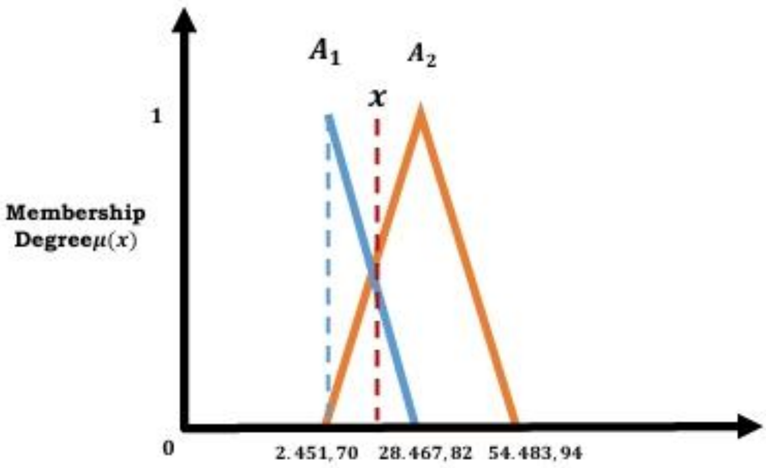

Figure 3. Membership Degree Triangle Curve

Based on the triangular curve of the fuzzy set A_1 above, it can be seen that the value $x = 16.837.410.000$ is on the right side of the curve. Thus, based on the curve, the following values are obtained:
$b = 2.451.700.000$
$c = 28.467.820.000$
Due to the x located on $b < x < c$ so that for the calculation of the value of membership $x = 16.837,41$ on the fuzzy set triangle curve A_1 obtained as follows:

$$\mu_{x_1}(x) = \frac{c - x}{c - b} = \frac{28.467.820.000 - 16.837.410.000}{28.467.820.000 - 2.451.700.000} = 0,44$$

Based on the triangular curve of the fuzzy set A_2 above, it can be seen that the value $x = 16.837.410.000$ is on the right side of the curve. Thus, based on the curve, the following values are obtained:
$a = 2.451.700.000$
$b = 28.467.820.000$
$c = 54.483.940.000$
Due to the x located on $a < x < b$ so that for the calculation of the value of membership $x = 16.837,41$ on the fuzzy set triangle curve A_1 obtained as follows:

$$\mu_{x_1}(x) = \frac{x - a}{b - a} = \frac{16.837.410.000 - 2.451.700.000}{28.467.820.000 - 2.451.700.000} = 0,55$$

Step 5. Determining the fuzzification of PT Taspen (Persero) profit data
For example, for PT Taspen (Persero)'s profit data for April 2023, namely $x = 16.837,41$. The data is located in a fuzzy set A_1 and A_2 with the value of each membership 0,44 and 0,55. The determination

of data fuzzification is obtained by looking for the maximum membership value. Based on the maximum membership value, namely $A_1 < A_2$, then the results of the data fuzzification in May 2023 are $x = 16.837.410.000$ was A_1or it can be categorized as very low. The results of the fuzzification of PT Taspen (Persero)'s profit data are presented in the following table:

Table 3. Fuzzification of PT Taspen (Persero) Profit Data

Period (t)	Profit Date	Fuzzification	FLR
May-23	16.837,41	A_1	NA
Jun-23	46.094,88	A_3	$A_1 \rightarrow A_3$
Jul-23	35.576,21	A_2	$A_3 \rightarrow A_2$
Aug-23	41.923,17	A_2	$A_2 \rightarrow A_2$
Sep-23	82.351,57	A_4	$A_2 \rightarrow A_4$
Oct-23	65.025,61	A_4	$A_4 \rightarrow A_4$
Nov-23	97.805,04	A_5	$A_4 \rightarrow A_5$
Dec-23	106.516,18	A_5	$A_5 \rightarrow A_5$
Jan-24	2.451,70	A_1	$A_5 \rightarrow A_1$
Feb-24	5.654,92	A_1	$A_1 \rightarrow A_1$
Mar-24	10.394,33	A_1	$A_1 \rightarrow A_1$
Apr-24	8.732,71	A_1	$A_1 \rightarrow A_1$
May-24	14.711,99	A_1	$A_1 \rightarrow A_1$
Jun-24	22.606,17	A_1	$A_1 \rightarrow A_1$
Jul-24	19.202,57	A_1	$A_1 \rightarrow A_1$

Step 6. Defining Fuzzy Logic Relations Group (FLRG)
The next stage is the formation of FLRG using FLR which has LHS (Left Hand Side) or FLR with fuzzy set which has $(t - 1)$ the same in the profit of PT Taspen (Persero). The FLRG obtained is as follows:

Table 4. FLRG Profit Data of PT Taspen (Persero)

FLRG	
$A_1 \rightarrow$	A_1, A_3
$A_2 \rightarrow$	A_2, A_4
$A_3 \rightarrow$	A_2
$A_4 \rightarrow$	A_4, A_5
$A_5 \rightarrow$	A_5

Step 7. Forecasting and Defuzzification
The next stage is forecasting and defuzzification which describes the process of converting the results of fuzzy logic relations (FLR) into quantitative values or actual predictions. After processing, the overall results of PT Taspen (Persero) profit data forecasting using the fuzzy time series method were obtained as follows:

Table 5. Overall Profit Data Forecasting of PT Taspen (Persero)

Period	Profit	Divination
May-23	16.837,41	NA
Jun-23	46.094,88	90.606,7
Jul-23	35.576,21	45.303,3
Aug-23	41.923,17	153.045
Sep-23	82.351,57	153.045
Oct-23	65.025,61	246.703

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Nov-23	97.805,04	246.703
Dec-23	106.516,18	138.961
Jan-24	2.451,70	138.961
Feb-24	5.654,92	90.606,7
Mar-24	10.394,33	90.606,7
Apr-24	8.732,71	90.606,7
May-24	14.711,99	246.703
Jun-24	22.606,17	90.606,7
Jul-24	19.202,57	90.606,7

B. PT Taspen Profit Forecasting Using *Cheng's Fuzzy Time Series*

Step 1. The formation of the set of the universe (U). The first step in calculating fuzzy time series using Cheng is to form a universal set. In this case, the author sets D1 to 3 and D2 to 5.
The first step in calculating fuzzy time series with cheng is to form a set of universes.
In this case, the author specifies D1 as 3 and D2 as 5. The calculation is as follows:

$$U = [D_{min}\ ;\ D_{max}]$$
$$= [2.451.700.000\ ; 106.516.180.000]$$

Step 2. Interval formation

The next step for the fuzzy time series cheng method is to form a class interval as follows:
Define the range.

$$R = 106.516.180.000 - 2.451.700.000$$
$$= 104.064.480.000$$

Determine the number of class intervals using the sturges equation.

$$I = \frac{Range\ (R)}{(k)}$$
$$= \frac{104.064.480.000}{5}$$
$$= 20.812.896.000$$

Find the middle value

Table 6. Central Value of PT Taspen (Persero) Profit Data

Lower Limit	Upper Limit	Middle Value
	2.448.700.000	
2.448.700.000	23.261.596.000	12.855.148.000
23.261.596.000	44.074.492.000	33.668.044.000
44.074.492.000	64.887.388.000	54.480.940.000
64.887.388.000	85.700.284.000	75.293.836.000
85.700.284.000	106.513.180.000	96.106.732.000

Step 3. Define a *fuzzy* set

The frequency with the first most number is divided into i the same interval to represent a more detailed degree of membership. The second most frequency is then divided into $i-1$ interval, and the third most frequency becomes $i-2$ intervals, and so on. This process continues to be carried out gradually until the remaining frequencies no longer allow for further division, resulting in a fuzzy representation that is proportional and reflects the data distribution more accurately.

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This process continues to be carried out gradually until the remaining frequencies no longer allow for further division.

Table 7. Central Value of PT Taspen (Persero) Profit Data

Fuzzification	Categori
A_1	Very Low
A_2	Low
A_3	Intermediate
A_4	Tall
A_5	Very High

Step 4. Fuzzification of historical data

Every fuzzy set A_i has a membership function $\mu A_i(u)$ that maps each element $u \in U$ into the degree of membership in the range [0,1] according to its linguistic meaning, such as "low", "medium", or "high". The next step is to define fuzzy sets A_1,A_2,…,A_n in the universe of discourse U, which represent the linguistic values of a linguistic variable. Each fuzzy set A_i has a membership function μA_i(u) that maps each element u∈U into a membership degree in the range [0,1], according to its linguistic meaning, such as "low", "medium", or "high". This process is then continued with fuzzification, which is converting the actual observed data into the form of membership degree values for each A_i, so that the deterministic crisp data can be represented in a fuzzy form that reflects uncertainty and ambiguity more realistically.

Step 5. Define and create a Fuzzy Logic Relations (FLR) table

This FLR represents the logical relationship between two fuzzy sets based on the time sequence of the fuzzified data. The next step in the Fuzzy Time Series method is to form a Fuzzy Logical Relationship (FLR) symbolized by A_i→A_j, where A_i is called the current state and A_j is called the next state. This FLR represents a logical relationship between two fuzzy sets based on the time sequence of the fuzzified data. That is, if at time t the data is in the fuzzy set A_i, and at time t+1 the data is in the fuzzy set A_j, then the FLR relationship A_i→A_j is formed. This relationship is the basis for building a prediction model, because it reflects the pattern of changes in variable values over time in a linguistic form that has been transformed fuzzy.

Table 8. FLR Profit Data of PT Taspen (Persero)

CS	NS	COUNTA of NS
A_1	A_1	7
	A_3	1
A_2	A_2	1
	A_4	1
A_3	A_2	1
A_4	A_1	1
	A_4	1
A_5	A_1	1
	A_5	1

Based on the Fuzzy Logical Relationship (FLR) table provided, it can be seen that each Current State (CS) has one or more Next State (NS) that appear based on the frequency of their occurrence (COUNTA of NS). For example, CS A_1 has two NS namely A_1 as many as 7 times and A_3 as many as 1 time, indicating that from state A_1, the system tends to remain in A_1 but also has the possibility of moving to A_3. CS A_2 has NS A_2 and A_4, each once, indicating the existence of variations in movement in both directions. CS A_3 only moves to A_2 once, while CS A_4 has two possibilities, namely remaining in A_1 and moving to A_4, each once.

Step 6. Determining the weight of FLR relations into a Fuzzy Logic Relations Group (FLRG)

The next step is to input all the fuzzy logical relationships (FLRs) that have been formed and assign weights based on the order and frequency of occurrence of the same relationship. FLRs that have the same current state (A_i) will be grouped into one Fuzzy Logical Relationship Group (FLRG), then organized into a weighting matrix. Each repeated relationship A_i → A_j will have its occurrences counted and used as the basis for assigning weights. Every relationship $A_i \rightarrow A_j$ that are repeated will be calculated in the number of occurrences and used as the basis for giving weight, So that relationships that appear more often will have greater weight than those that rarely occur.

Table 9. Profit Data Weighting Matrix of PT Taspen (Persero)

	A_1	A_2	A_3	A_4	A_5
A_1	7	0	1	0	0
A_2	0	1	0	1	0
A_3	0	1	0	0	0
A_4	1	0	0	1	0
A_5	1	0	0	0	1

Step 7. Transfer the FLRG weight into the form of a standardized weighting matrix (W^*)
The next step is to transfer the weights from the Fuzzy Logical Relationship Group (FLRG) into a standardized or normalized weighting matrix. This process is done by dividing each value in the initial weighting matrix row by the total number of values in that row, resulting in a proportional weight value in the range of 0 to 1. This normalization aims to convert absolute frequencies into transition probabilities from a current state (A_i) to various possible next states (A_j).
This process is done by dividing each value in the initial weighting matrix row by the total number of values on that row, resulting in a proportional weight value that is in the range of 0 to 1.

Table 10. Standardized Matrix of PT Taspen (Persero) Profit Data

	A_1	A_2	A_3	A_4	A_5
A_1	0,875	0	0,125	0	0
A_2	0	0,5	0	0,5	0
A_3	0	1	0	0	0
A_4	0,5	0	0	0,5	0
A_5	0,5	0	0	0	0,5

The matrix above shows the normalized result of the previous weighting matrix, where each value in a row represents the probability of transition from the current state (A_i) to the next state (A_j). For example, in row A_1, the value of 0.875 in column A_1 and 0.125 in column A_3 indicates that from state A_1, there is an 87.5% probability of remaining in A_1 and a 12.5% probability of moving to A_3. Row A_2 has a balanced probability distribution, 0.5 for A_2 and A_4, respectively. Meanwhile, A_3 only has a full probability (1.0) of moving to A_2. Similarly, A_4 shows an equal probability of moving to A_4 or A_5 (0.5 each), and A5 has a balanced probability of moving to A_1 or remaining in A_5.
Step 8. Determining the defuzification of the forecast value
The next stage is forecasting and defuzzification, which describes the process of converting the results of fuzzy logic relations (FLRs) into quantitative values or actual predictions. Defuzzification is performed by taking the midpoint of each interval of the fuzzy set, which reflects the best estimate of the fuzzified data. If a fuzzy set has no relation (a single FLR), then forecasting is performed using the midpoint of that set.
Defuzzification is performed by taking the middle value of each *fuzzy* set interval, which reflects the best estimate of the data that has been fuzzified. If a fuzzy set has no relation (single FLR), then the forecasting is done using the middle value of that set. After processing, the overall results of PT Taspen (Persero) profit data forecasting using the *fuzzy time series cheng* method were obtained as follows:

Table 11. Overall Forecasting of the Cheng Method of PT Taspen (Persero) Profit Data

Period	Profit	Divination
May-23	16.837,41	NA
Jun-23	46.094,88	33.670,444
Jul-23	35.576,21	54.484,94
Aug-23	41.923,17	54.484,94
Sep-23	82.351,57	37.649,718
Oct-23	65.025,61	37.649,718
Nov-23	97.805,04	54.484,94
Dec-23	106.516,18	54.484,94
Jan-24	2.451,70	18.059,572
Feb-24	5.654,92	18.059,572
Mar-24	10.394,33	18.059,572
Apr-24	8.732,71	18.059,572
May-24	14.711,99	18.059,572
Jun-24	22.606,17	18.059,572
Jul-24	19.202,57	18.059,572

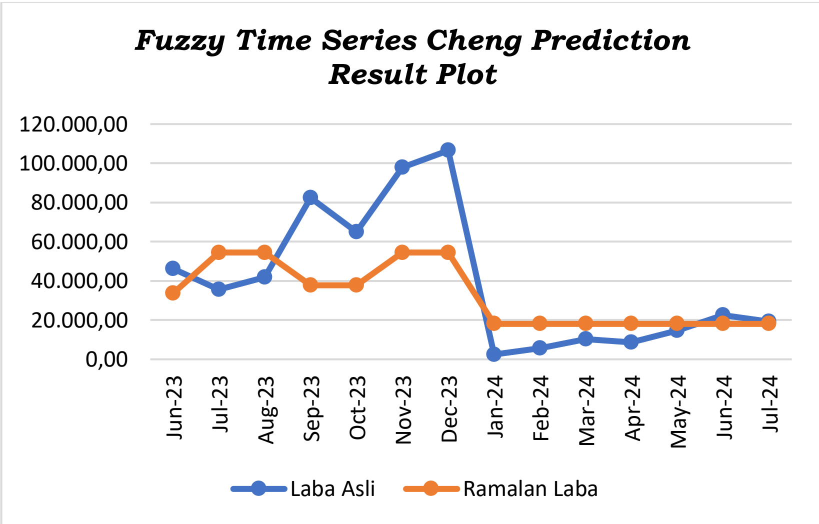

Figure 4. Fuzzy Time Series Cheng Prediction Result Plot Profit PT Taspen (Persero)

C. Measurement of the Accuracy of PT Taspen's Profit Forecasting

In this section, an evaluation was carried out on the accuracy of PT Taspen's profit forecasting results using *the Fuzzy Time Series Chen* and *Fuzzy Time Series Cheng methods* through three error measures, namely *Mean Absolute Percentage Error* (MAPE), *Mean Squared Error* (MSE), and *Mean Absolute Error* (MAE).

Table 12. Accuracy of Forecasting Method Cheng Profit Data of PT Taspen (Persero)

Error Absolute Chen	*Error Absolute Cheng*
3.769,27	1.222,16
4.511,80	1.424,44
.727,13	1.908,73
1.122,20	1.561,77
.693,80	4.701,85
1.677,79	2.375,89

	1.898,36	.320,10
	.445,19	.031,24
	.509,67	.607,87
	.951,76	.404,65
	.212,35	.665,24
	.873,97	.326,86
	1.991,41	.347,58
	.000,51	.546,60
	.404,11	1.143,00
MAPE	0,674	0,603
MSE	3.303	2.684
MAE	1.319,29	1.172,53

In particular, the MAPE value of Cheng's method shows that the forecast relative error to the actual value is smaller, so Cheng's method is more reliable and worthy of consideration in projecting PT Taspen (Persero's profit).

4. CONCLUSION

Based on the results of the description that has been discussed in the previous chapter, it can be concluded:

1. Based on the results of the analysis, Cheng's Fuzzy Time Series method resulted in a higher level of accuracy in PT Taspen (Persero's) profit forecasting than Chen's Fuzzy Time Series method, as indicated by the lower MAPE, MSE, and MAE values. The cheng method is also better able to follow the fluctuating trend of actual profit so that it can be a more reliable approach to projecting PT Taspen's profit.
2. The results of this study show that the cheng method has the potential to be applied in financial planning and decision-making. For further research, it is recommended to develop this method by combining other Fuzzy Time Series methods.

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Application of *Runge Kutta Fehlberg* (RKF45) Method as a Numerical Analysis to SIR Model of Tuberculosis Transmission in Central Java

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ABSTRACT

This study uses a three-compartment SIR model for the spread of tuberculosis in Central Java. Changes in individuals detected, recovered, died naturally, and died due to tuberculosis affect disease transmission. Numerical simulations were used to validate the analysis results and identify the main parameters that most contribute to disease spread among susceptible, infected, quarantined, and recovered individuals. The numerical method used is *Runge Kutta Fehlberg.* Using this method, a quantitative description of the number of susceptible, infected, and recovered populations is obtained, which can assist the Central Java Health Office in its efforts to prevent and control the spread of tuberculosis. The SIR model obtained from determining the parameters is then solved using the Runge Kutta Fehlberg method. The results obtained using data from 2021-2023 show that the initial value for *Susceptible* is 111.120.397, the initial value *for Infected* is 157.024, and the initial value *for Recovered* is 38.452, with a birth rate parameter of 0,013043, a natural death rate of 0,001287, a tuberculosis death rate of 0,041376, a transmission rate from susceptible to infected of 0,001411, and a recovery rate from infected to recovered of 0,24488 people. In year 50, there were 35.073.325 *susceptible* individuals, the number *of infected individuals* in the 50th year is 0,04, and the number of *recovered individuals* in the 50th year is 74.774. The number of tuberculosis infection cases decreases from year to year.

Keyword : Epidemiology, Mathematical Modeling, Numerical Analysis, Runge Kutta Fehlberg, SIR, Tuberculosis.

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1. INTRODUCTION

Along with the development of science and technology, the discipline of mathematics has developed rapidly. Mathematics can be applied in various sectors. For example, biomedical mathematics is the application of mathematics in biology (Hurit et al, 2022). In mathematical modeling, mathematical models can describe complex abstract events and become *problem solving* in the world of health. Mathematical models are very diverse, and as mathematics develops, many mathematical models are created(Ndii, 2018). A widely used mathematical model that produces accurate solutions is the *Susceptible, Infected, Recovered* (SIR) mathematical model. This mathematical model is used to predict a phenomenon based on transmission (Moujahid & Vadillo, 2021). The SIR model is commonly used to predict the transmission of infectious diseases within a certain period of time, such as in the research by (Sifriyani & Rosadi, 2020) to see the estimated reproduction number of Covid-19. The SIR mathematical model is one of the models used in epidemiology to represent the spread of infectious diseases in a particular population by describing the dynamics of the number of individuals in the population with three components, namely S (*Susceptible)* individuals who are vulnerable to infection, I (*Infected)* individuals who are infected with the disease, and R (*Recovered)* individuals who have recovered from the disease. Epidemiological models are very suitable for presenting the transmission rate of infectious diseases such as tuberculosis (TB) because the SIR model can present information that is in line with the data obtained, namely that there are three components*:* *Susceptible, Infected*, and *Recovered* (Yudasubrata, 2018).

In developing countries such as Indonesia, dealing with infectious diseases is a daunting task. According to the Indonesian Central Statistics Agency (BPS), Indonesia's population in 2021-2023 will be 281,603,800. Tuberculosis in Indonesia is a major concern. Tuberculosis (TB) is an infectious disease caused by the *Mycobacterium tuberculosis* bacterium, which is transmitted through the air and attacks organs such as the lungs, kidneys, brain, spine, and lymph nodes. According to the WHO, throughout 2022, the second deadliest infectious disease after Covid-19 was tuberculosis. According to TB Indonesia (TB Indonesia, 2024), Indonesia ranks second with the highest number of TB cases in the world after India, followed by China. With the highest number of TB cases nationally, Central Java province has a fairly high

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number of TB cases. The high prevalence of TB cases certainly requires special attention and effective measures to prevent the spread of TB. In dealing with the spread of TB, it can be done not only in the health sector, but also by utilizing mathematical modeling to help predict TB transmission using the SIR mathematical model(Nafsi & Rahayu, 2020). The SIR model was first introduced by Kermack and McKendrick in 1927 and is still widely used in epidemiological studies today(Ningsih & Mungkasi, 2020). In this model, the rate of movement of individuals between subpopulations is described using a system *of ordinary differential equations* (ODE)(Purnomo Dwi, 2012). By using the SIR model systematically, we can observe the dynamics of TB spread.

Research related to mathematical modeling, namely the SIR model, includes Bahari et al.'s (Bahari et al, 2021) study on the SIR spread of tuberculosis in Central Java. followed by numerical research by Rif'at et al. (Rif'at et al, 2022) on the analysis of the spread rate of Covid-19 using the SIR epidemiological mathematical model and fourth-order *Runge Kutta* in the city of Surabaya. Furthermore, there is numerical solution research by Anwar et al. (Anwar et al, 2023) on the numerical solution of the SIR model in the spread of tuberculosis using the *Runge Kutta Fehlberg* (RKF45) method.

The *Runge Kutta Fehlberg* (RKF45) method is one of the numerical methods widely used to solve differential equations (Al-Bugami & Al-Juaid, 2020). RKF45 is a numerical algorithm resulting from the modification of the fourth-order *Runge Kutta* method and the fifth- order *Runge Kutta* method used in solving ordinary differential equations with a high degree of accuracy (Ghazal & Hussain, 2021). High accuracy occurs because this model has six constants. The RKF45 method is a frequently used and popular numerical method (Anwar et al, 2023). According to the introduction, this study aims to determine the SIR model and the numerical solution of the SIR mathematical model in the transmission of tuberculosis in Central Java by applying the RKF45 numerical method(Suryaningrat et al, 2020). The solution obtained will be considered by the Central Java Provincial Health Office in responding to tuberculosis cases by eradicating transmission to minimize the spread of tuberculosis in Central Java Province.

2. RESEARCH METHOD

This research was conducted to see the success of using the RKF45 mixed analysis method to solve the SIR Mathematical model on the spread of tuberculosis disease over a period of 3 years. This research was completed through five stages, namely planning, implementation, data collection, modeling, and application of the RKF45 method. This research was conducted in Central Java using tuberculosis patient data from 2021 to 2023.

The materials used for this study are secondary data from the Central Statistics Agency (BPS) of Central Java Province and the Central Java Provincial Health Office which were obtained in 2024. The collected quantitative data was processed through the SIR mathematical model analysis stage to obtain an overview of the spread of the disease from 2021 to 2023. The next stage is to enter the model into the RKF45 equation using Matlab software, this stage is the final stage in the analysis which produces predicted results for the number of susceptible, infected, and recovered individuals in the next 50 years.

3. RESULTS AND DISCUSSION

The mathematical model for the spread of tuberculosis (SIR) in Central Java can be observed through secondary data calculations adapted to the formulas used in the SIR model analysis. This model is expected to provide an overview and prediction of the spread of tuberculosis in Central Java, enabling responsible parties to provide prevention and control measures for tuberculosis cases in the region. The SIR model analysis for tuberculosis in Central Java is presented in the table below:

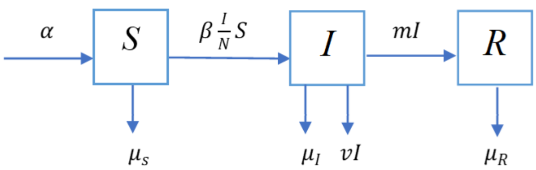

Figure 4. SIR Tuberculosis Model

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The image above is a picture of the tuberculosis SIR model that corresponds to the conditions of tuberculosis spread in Central Java from 2021 to 2023. Explanations of the mathematical symbols can be seen in tables 1 and 2 below. From the SIR tuberculosis mathematical model image above, the following model equation is obtained:

$$\frac{dS}{dt} = \alpha - \beta \frac{I}{N} S - \mu_s$$

$$\frac{dI}{dt} = \beta \frac{I}{N} S - mI - \mu_I - vI$$

$$\frac{dR}{dt} = mI - \mu_R$$

Table 13. Variable Of SIR Model

Variables	Definition	Value	Information
S_0	Early susceptible	111.120.397	Data on the number of individuals susceptible to tuberculosis in Central Java in 2021-2023
I_0	Early infected	157.024	Data on the number of individuals infected (positive) with tuberculosis in Central Java in 2021-2023
R_0	Earl recovered	38.452	Data on the number of individuals recovered from tuberculosis in Central Java in 2021-2023

Source: Data processed by researchers

Table 1 lists the variable names used in SIR modeling. The obtained data are then labeled with variables, such as S for the number of individuals susceptible to the disease, I for individuals infected with the disease, and R for individuals recovered. The small number 0 below the symbol represents the initial data or data before analysis

Table 14. Parameters Of SIR Model

Parameters	Definition	Formulation	Value
α	Birth rate	$\alpha = \frac{total\ of\ birth}{total\ population}$	0,013043
μ	Natural death rate	$\mu = \frac{natural\ death\ total}{total\ population}$	0,001287
ν	Death rate from tuberculosis	$\nu = \frac{total\ of\ deaths\ due\ to\ TB}{total\ TB\ infections}$	0,041376
β	Transmission rate from susceptible to infected	$\beta = \frac{total\ of\ infections}{total\ of\ population}$	0,001411
m	rate of recovery from infected to cured	$m = \frac{total\ of\ recovered}{total\ of\ infections}$	0,24488

Source: Data processed by researchers

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Table 2 lists the parameter values required for the SIR and RKF45 model analyses. The symbols used have their own meanings; the SIR and RKF45 model analyses require five parameters that represent characteristics within the population.

From the results of the parameter calculations in the table 2. Substitute into the Central Java tuberculosis SIR model, with the results in the equation below:

$$\frac{dS}{dt} = 0{,}01304 - 0{,}00141\frac{I}{N}S - 0{,}001284S$$

$$\frac{dI}{dt} = 0{,}00141\frac{I}{N}S - 0{,}24488I - 0{,}00128I - 0{,}04137I$$

$$\frac{dR}{dt} = 0{,}24488I - 0{,}00128R$$

The SIR mathematical model equation above will be used for the RKF45 numerical analysis method. The RKF45 numerical analysis equation can be seen in the equation below:

$$\hat{S}_{t+1} = S_i + \frac{16}{135}k\hat{S}_1 + \frac{6656}{12825}k\hat{S}_3 + \frac{28651}{56437}k\hat{S}_4 - \frac{9}{5}k\hat{S}_5 + \frac{2}{55}k\hat{S}_6$$

$$\hat{I}_{t+1} = I_i + \frac{16}{135}k\hat{I}_1 + \frac{6656}{12825}k\hat{I}_3 + \frac{28651}{56437}k\hat{I}_4 - \frac{9}{5}k\hat{S}_5 + \frac{2}{55}k\hat{I}_6$$

$$\hat{R}_{t+1} = R_i + \frac{16}{135}k\hat{R}_1 + \frac{6656}{12825}k\hat{R}_3 + \frac{28651}{56437}k\hat{R}_4 - \frac{9}{5}k\hat{R}_5 + \frac{2}{55}k\hat{R}_6$$

With the following counting constants:

$$k\hat{S}_1 = \Delta t\left(\alpha - \beta\frac{I}{N}S - \mu S\right)$$

$$k\hat{I}_1 = \Delta t\left(\beta\frac{I}{N}S - \mu I - \nu I - mI\right)$$

$$k\hat{R}_1 = \Delta t(mI - \mu R)$$

$$k\hat{S}_2 = \Delta t(\alpha - \beta\left(\frac{I}{N} + kI_1\frac{1}{4}\right)\left(S_i + k\hat{S}_1\frac{1}{4}\right)\left(I_t + k\hat{I}_1\frac{1}{4}\right) - \mu(S_t + k\hat{S}_1\frac{1}{4})$$

$$k\hat{I}_2 = \Delta t(\beta\left(\frac{I}{N} + kI_1\frac{1}{4}\right)\left(S_t + k\hat{S}_1\frac{1}{4}\right)\left(I_t + k\hat{I}_1\frac{1}{4}\right) - \mu\left(I_t + k\hat{I}_1\frac{1}{4}\right) - \nu\left(I_t + k\hat{I}_1\frac{1}{4}\right) - m(I_t + k\hat{I}_1\frac{1}{4})$$

$$k\hat{R}_2 = \Delta t(m\left(I_t + k\hat{I}_1\frac{1}{4}\right) - \mu(R_t + k\hat{R}_1\frac{1}{4})$$

$$k\hat{S}_3 = \Delta t(\alpha - \beta\left(\frac{I}{N} + k\hat{I}_1\frac{3}{32} + k\hat{I}_2\frac{9}{32}\right)\left(S_t + k\hat{S}_1\frac{3}{32} + k\hat{S}_2\frac{9}{32}\right)\left(I_t + k\hat{I}_1\frac{3}{32} + k\hat{I}_2\frac{9}{32}\right) - \mu(S_t + k\hat{S}_1\frac{3}{32} + k\hat{S}_2\frac{9}{32})$$

$$k\hat{I}_3 = \Delta t(\beta\left(\frac{I}{N} + k\hat{I}_1\frac{3}{32} + k\hat{I}_2\frac{9}{32}\right)\left(S_t + k\hat{S}_1\frac{3}{32} + k\hat{S}_2\frac{9}{32}\right)\left(I_1 + k\hat{I}_1\frac{3}{32} + k\hat{I}_2\frac{9}{32}\right) - \mu\left(I_t + k\hat{I}_1\frac{3}{32} + k\hat{I}_2\frac{9}{32}\right) - \nu\left(I_t + k\hat{I}_1\frac{3}{32} + k\hat{I}_2\frac{9}{32}\right) - m(I_t + k\hat{I}_1\frac{3}{32} + k\hat{I}_2\frac{9}{32})$$

$$k\hat{R}_3 = \Delta t(m\left(I_t + k\hat{I}_1\frac{3}{32} + k\hat{I}_2\frac{9}{32}\right) - \mu(R_t + k\hat{R}_1\frac{3}{32} + k\hat{R}_2\frac{9}{32})$$

$$k\hat{S}_4 = \Delta t(\alpha - \beta\left(\frac{I}{N} + k\hat{I}_1\frac{3}{4} - \frac{3}{16}k\hat{I}_2 + \frac{9}{16}k\hat{I}_3\right)\left(S_t + k\hat{S}_1\frac{3}{4} - \frac{3}{16}k\hat{S}_2 + \frac{9}{16}k\hat{S}_3\right)\left(I_t + k\hat{I}_1\frac{3}{4} - \frac{3}{16}k\hat{I}_2 + \frac{9}{16}k\hat{I}_3\right) - \mu(S_t + k\hat{S}_1\frac{3}{4} - \frac{3}{16}k\hat{S}_2 + \frac{9}{16}k\hat{S}_3)$$

$$k\hat{I}_4 = \Delta t(\beta\left(\frac{I}{N} + k\hat{I}_1\frac{3}{4} - \frac{3}{16}k\hat{I}_2 + \frac{9}{16}k\hat{I}_3\right)\left(S_t + k\hat{S}_1\frac{3}{4} - \frac{3}{16}k\hat{S}_2 + \frac{9}{16}k\hat{S}_3\right)\left(I_t + k\hat{I}_1\frac{3}{4} - \frac{3}{16}k\hat{I}_2 + \frac{9}{16}k\hat{I}_3\right) - \mu\left(I_t + k\hat{I}_1\frac{3}{4} - \frac{3}{16}k\hat{I}_2 + \frac{9}{16}k\hat{I}_3\right) - \nu\left(I_t + k\hat{I}_1\frac{3}{4} - \frac{3}{16}k\hat{I}_2 + \frac{9}{16}k\hat{I}_3\right) - m(I_t + k\hat{I}_1\frac{3}{4} - \frac{3}{16}k\hat{I}_2 + \frac{9}{16}k\hat{I}_3)$$

$$k\hat{R}_4 = \Delta t(m\left(I_t + k\hat{I}_1\frac{3}{4} - \frac{3}{16}k\hat{I}_2 + \frac{9}{16}k\hat{I}_3\right) - \mu(R_t + k\hat{R}_1\frac{3}{4} - \frac{3}{16}k\hat{R}_2 + \frac{9}{16}k\hat{R}_3)$$

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$$k\hat{S}_5 = \Delta t(\alpha - \beta\left(\frac{I}{N} + k\hat{I}_1\frac{439}{216} - 8k\hat{I}_2 + \frac{3860}{513}k\hat{I}_3 - \frac{845}{4104}k\hat{I}_4\right)\left(S_t + k\hat{S}_1\frac{439}{216} - 8k\hat{S}_2 + \frac{3860}{513}k\hat{S}_3 - \frac{845}{4104}k\hat{S}_4\right)\left(I_t + k\hat{I}_1\frac{439}{216} - 8k\hat{I}_2 + \frac{3860}{513}k\hat{I}_3 - \frac{845}{4104}k\hat{I}_4\right) - \mu(S_t + k\hat{S}_1\frac{439}{216} - 8k\hat{S}_2 + \frac{3860}{513}k\hat{S}_3 - \frac{845}{4104}k\hat{S}_4)k\hat{I}_5$$

$$k\hat{I}_5 = \Delta t(\beta\left(\frac{I}{N} + k\hat{I}_1\frac{439}{216} - 8k\hat{I}_2 + \frac{3860}{513}k\hat{I}_3 - \frac{845}{4104}k\hat{I}_4\right)\left(S_t + k\hat{S}_1\frac{439}{216} - 8k\hat{S}_2 + \frac{3860}{513}k\hat{S}_3 - \frac{845}{4104}k\hat{S}_4\right)\left(I_1 + k\hat{I}_1\frac{439}{216} - 8k\hat{I}_2 + \frac{3860}{513}k\hat{I}_3 - \frac{845}{4104}k\hat{I}_4\right) - \mu\left(I_t + k\hat{I}_1\frac{439}{216} - 8k\hat{I}_2 + \frac{3860}{513}k\hat{I}_3 - \frac{845}{4104}k\hat{I}_4\right) - \nu\left(I_t + k\hat{I}_1\frac{439}{216} - 8k\hat{I}_2 + \frac{3860}{513}k\hat{I}_3 - \frac{845}{4104}k\hat{I}_4\right) - m(I_t + k\hat{I}_1\frac{439}{216} - 8k\hat{I}_2 + \frac{3860}{513}k\hat{I}_3 - \frac{845}{4104}k\hat{I}_4)$$

$$k\hat{S}_6 = \Delta t(\alpha - \beta\left(\frac{I}{N} - k\hat{I}_1\frac{8}{27} + 2k\hat{I}_2 - \frac{3544}{2565}k\hat{I}_3 - \frac{1859}{4104}k\hat{I}_4 - \frac{11}{40}k\hat{I}_5\right)\left(S_t - k\hat{S}_1\frac{8}{27} + 2k\hat{S}_2 - \frac{3544}{2565}k\hat{S}_3 - \frac{1859}{4104}k\hat{S}_4 - \frac{11}{40}k\hat{S}_5\right)\left(I_t - k\hat{I}_1\frac{8}{27} + 2k\hat{I}_2 - \frac{3544}{2565}k\hat{I}_3 - \frac{1859}{4104}k\hat{I}_4 - \frac{11}{40}k\hat{I}_5\right) - \mu(S_t - k\hat{S}_1\frac{8}{27} + 2k\hat{S}_2 - \frac{3544}{2565}k\hat{S}_3 - \frac{1859}{4104}k\hat{S}_4 - \frac{11}{40}k\hat{S}_5)$$

$$k\hat{I}_6 = \Delta t(\beta\left(\frac{I}{N} - k\hat{I}_1\frac{8}{27} + 2k\hat{I}_2 - \frac{3544}{2565}k\hat{I}_3 - \frac{1859}{4104}k\hat{I}_4 - \frac{11}{40}k\hat{I}_5\right)\left(S_t - k\hat{S}_1\frac{8}{27} + 2k\hat{S}_2 - \frac{3544}{2565}k\hat{S}_3 - \frac{1859}{4104}k\hat{S}_4 - \frac{11}{40}k\hat{S}_5\right)\left(I_1 - k\hat{I}_1\frac{8}{27} + 2k\hat{I}_2 - \frac{3544}{2565}k\hat{I}_3 - \frac{1859}{4104}k\hat{I}_4 - \frac{11}{40}k\hat{I}_5\right) - \mu\left(I_t - k\hat{I}_1\frac{8}{27} + 2k\hat{I}_2 - \frac{3544}{2565}k\hat{I}_3 - \frac{1859}{4104}k\hat{I}_4 - \frac{11}{40}k\hat{I}_5\right) - \nu\left(I_t - k\hat{I}_1\frac{8}{27} + 2k\hat{I}_2 - \frac{3544}{2565}k\hat{I}_3 - \frac{1859}{4104}k\hat{I}_4 - \frac{11}{40}k\hat{I}_5\right) - m(I_t - k\hat{I}_1\frac{8}{27} + 2k\hat{I}_2 - \frac{3544}{2565}k\hat{I}_3 - \frac{1859}{4104}k\hat{I}_4 - \frac{11}{40}k\hat{I}_5)$$

$$k\hat{R}_6 = \Delta t(m\left(I_t - k\hat{I}_1\frac{8}{27} + 2k\hat{I}_2 - \frac{3544}{2565}k\hat{I}_3 - \frac{1859}{4104}k\hat{I}_4 - \frac{11}{40}k\hat{I}_5\right) - \mu(R_t - k\hat{R}_1\frac{8}{27} + 2k\hat{R}_2 - \frac{3544}{2565}k\hat{R}_3 - \frac{1859}{4104}k\hat{R}_4 - \frac{11}{40}k\hat{R}_5)$$

Using MATLAB software, numerical solutions for the SIR mathematical model of tuberculosis spread were obtained using the *Runge Kutta Fehlberg* (RKF45) method. The results of 50 iterations can be seen in Table 3 below:

Table 15. Results Analysis Of The Runge Kutta Fehlberg Method

Year	Iteration	S	I	R
2024	0	37451717,00	71550,00	17695,00
2025	1	37402495,16	53751,60	33050,62
2026	2	37353367,32	40372,12	44567,86
2027	3	37304326,10	30330,35	53185,93
2028	4	37255365,83	22791,80	59629,73
2029	5	37206482,11	17115,48	64456,07
2030	6	37157671,92	12862,45	68046,24
2031	7	37108932,71	9664,22	70720,32
2032	8	37060262,64	7257,95	72706,63
2033	9	37011660,37	5455,28	74168,80
2034	10	36963124,76	4097,61	75244,57
2035	11	36914655,00	3077,89	76026,94
2036	12	36866250,48	2313,49	76587,67
2037	13	36817910,66	1737,36	76985,01

2038	14	36769635,17	1305,30	77257,36
2039	15	36721423,67	980,97	77436,27
2040	16	36673275,91	736,64	77545,83
2041	17	36625191,68	553,58	77602,31
2042	18	36577170,78	415,91	77619,50
2043	19	36529213,07	312,35	77607,20
2044	20	36481318,41	234,76	77572,48
2045	21	36433486,67	176,33	77521,25
2046	22	36385717,74	132,45	77457,52
2047	23	36338011,50	99,55	77384,38
2048	24	36290367,87	74,76	77304,34
2049	25	36242786,75	56,17	77219,05
⋮	⋮	⋮	⋮	⋮
2073	49	35119370,82	0,06	74872,71
2074	50	35073325,13	0,04	74774,55

Source: Data processed by researchers

It can be seen in table 3 that the numerical solution of the Runge Kutta Fehlberg method for the SIR model shows that the spread of tuberculosis has decreased from year to year. Based on Table 3, with the initial conditions $S_0 = 111.120.397, I_0 = 157.024, R_0 = 38.452$ using RKF45 $S_{50} = 35.073.325, I_{50} = 0{,}04, R_{50} = 74.774$. The infected subpopulation will gradually disappear to 0. Based on the table, it can be seen that in 2073 the number of infected individuals will be less than 0. This shows a promising reduction in infection rates for Indonesia if there is good cooperation from all authorities handling TB cases.

The graph of numerical iteration results using the *Runge Kutta Fehlberg* method for the spread of tuberculosis for each *Susceptible*, *Infected*, and *Recovered individual* using MATLAB *software* is shown in Figure 2.

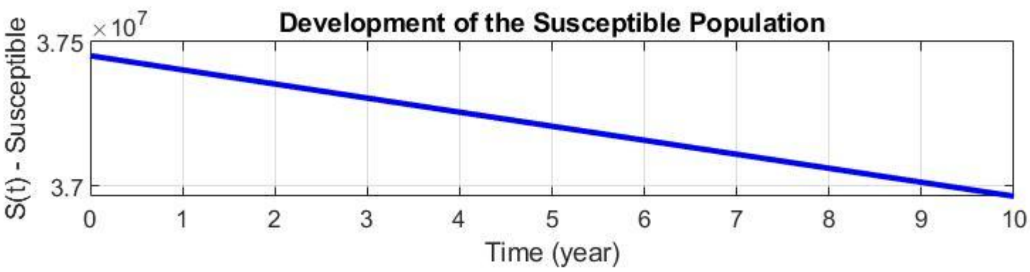

Figure 5. Development Of The Susceptible Population

Based on Figure 2, the susceptible population (blue line) decreases over time in the first 10 years, reaching 3.7, then gradually decreases until it reaches 0 in 50 years.

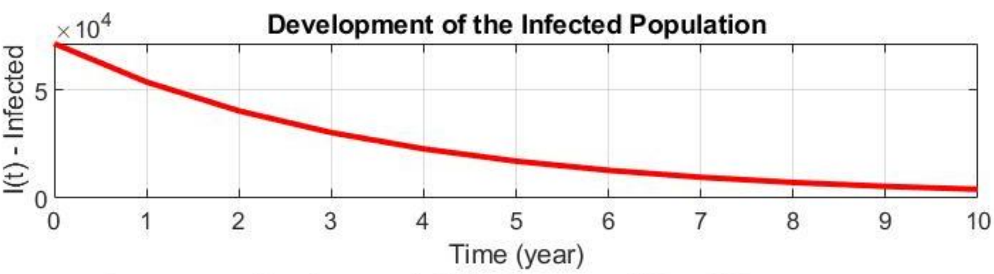

Figure 6. Development Of The Infected Population

Based on Figure 3, the infected population on the red line peaks at 0 years, indicating the infected population before iteration. Then the line decreases significantly to near 0 in the first 10 years. At 15 years, the line is already at 0 and continues to decline until the 50th year.

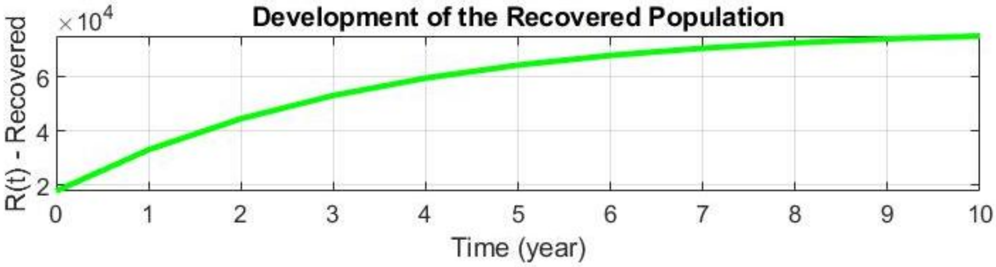

Figure 7. Development Of The Recovered Population

Based on Figure 4, which shows the development of the recovered population indicated by the green line. The recovered population line is at 0 at year 0, then increases in the first 15 years to its highest point, indicating that the recovered population dominates. At year 40, there is an insignificant change in number, namely a decrease. The decrease in the recovered population may be influenced by the number of deaths.

4. CONCLUSION

Based on the results of the Susceptible, Infected, Recovered (SIR) mathematical model for the spread of tuberculosis in Central Java, numerical results obtained using the Runge-Kutta-Fehlberg (RKF45) numerical method with a step size of $\Delta P = h = 1$ year and a time limit of 50 years indicate that the number of infected people is 104.126.462, less than one person is infected, and the number of recovered people is 162.079. Combining the RKF45 method to determine the numerical solution of the SIR mathematical model is still relevant for predicting the number of tuberculosis transmission cases over a long-time span.

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