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A Special Issue devoted to
Innovations and Solutions
to Shape the Future of Basic Education in the Era of Society 5.0

Guest Editor
Yusuf Hanafi

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Pertanika Journal of Social Sciences & Humanities
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PERTANIKA JOURNAL OF SOCIAL SCIENCES & HUMANITIES

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The *Introduction* explains the scope and objective of the study in the light of current knowledge on the subject; the *Materials and Methods* describes how the study was conducted; the *Results* section reports what was found in the study; and the *Discussion* section explains meaning and significance of the results and provides suggestions for future directions of research. The manuscript must be prepared according to the journal's **Instruction to Authors** (http://www.pertanika.upm.edu.my/Resources/regular_issues/Regular_Issues_Instructions_to_Authors.pdf).

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Preface

The rapid development of technology and changing educational needs have created new challenges and opportunities for basic education. In the era of Society 5.0, education must go beyond academic achievement by developing critical thinking, creativity, collaboration, communication, adaptability, and digital literacy. Learning innovation and research are therefore essential to support educational practices that are meaningful, responsive, and future-ready.

It is an honour to present this Special Issue, entitled "Learning Innovation and Research in Basic Education", with the theme "Innovations and Solutions to Shape the Future of Basic Education in the Era of Society 5.0". This collection brings together research on innovative learning approaches, assessment, digital technology, educational policy, and pedagogical practices that contribute to the development of basic education.

The studies presented highlight several important aspects of educational innovation. Research on STEM-PjBL and STEAM-integrated Project-Based Learning demonstrates the potential of interdisciplinary and project-based approaches to strengthen students' critical thinking, learning outcomes, communication, and collaboration. Studies on numeracy examine both the development of a REACT-based digital numeracy literacy instrument and the Adversity Quotient of future elementary school teachers, highlighting the importance of contextual assessment and resilience in learning.

Other contributions address learner diversity, teacher development, and digital learning. The review of fast-track education considers its academic and socio-psychological implications for gifted learners, while research on the "Platform Merdeka Mengajar" highlights the role of digital resources in empowering primary school educators. The study of children's literature further demonstrates how culturally relevant texts and narrative pedagogy can promote students' behavioural, emotional, and cognitive engagement.

Digital innovation is also explored through the development of a historical virtual tour on the Yellow War in Lasem, demonstrating the potential of immersive learning resources to strengthen students' understanding of historical content. In addition, research on final project guidance provides perspectives on multidisciplinary academic support, highlighting the importance of collaboration and effective guidance in educational settings.

Collectively, these contributions demonstrate that meaningful innovation is not limited to technology. It involves the integration of effective pedagogy, contextual assessment,

digital resources, teacher capacity, cultural relevance, and attention to learners' diverse needs. Such approaches are important in shaping an education system that is both technologically responsive and human-centred in the era of Society 5.0.

I sincerely appreciate all authors for their valuable contributions, the reviewers for their constructive evaluations, and the Editorial Team for their dedication and support. I hope that this Special Issue will encourage further research, collaboration, and innovation towards a more inclusive, meaningful, and future-ready basic education system.

Guest Editor
Yusuf Hanafi (Prof. Dr.)

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Exploring the Adversity Quotient (AQ) of Future Elementary School Teachers in Numeracy Problem Solving

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ABSTRACT

This study investigates the relationship between Adversity Quotient and mathematical thinking stages among prospective elementary school teachers. It focuses on three Adversity Quotient types: climbers, campers, and quitters. Participants included students from the Elementary School Teacher Education Study Programme. Data were collected through Adversity Quotient questionnaires and semi-structured interviews, analysed qualitatively through data reduction, interpretation, and conclusion drawing. Findings indicate that climber-type students effectively engage in all mathematical thinking stages: specialising, generalising, conjecturing, and convincing. In contrast, camper-type students often rely on irrelevant data, leading to pseudo-generalisation. Quitter-type students only attempt specialising and conjecturing stages, hindered by their limited thinking skills. The study highlights the importance of fostering a higher Adversity Quotient in students to enhance their mathematical problem-solving abilities.

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INTRODUCTION

Numeracy is increasingly recognised as a fundamental life skill that extends beyond the boundaries of mathematics. Reports from international large-scale assessments such as PISA and TIMSS consistently highlight the challenges faced

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by students in developing robust numeracy skills. Indonesia, like many developing nations, has been striving to improve its educational outcomes, yet difficulties persist in enabling students to reason numerically and apply mathematical knowledge to real-life contexts. This issue becomes even more pressing when considering the future role of elementary school teachers, who are expected to foster the early numeracy foundations critical for lifelong learning.

The importance of Adversity Quotient (AQ) in this discourse cannot be overstated. AQ embodies perseverance, problem-focused coping strategies, and resilience when facing complex tasks. In education, AQ complements constructs such as grit, resilience, and self-regulation, but it provides a more nuanced framework to explain how individuals persist or disengage when encountering mathematical challenges. For prospective elementary school teachers, cultivating a high AQ means equipping them not only with mathematical competencies but also with the emotional and cognitive endurance necessary to guide young learners in numeracy development. Therefore, embedding AQ in teacher education curricula is vital to prepare teachers who are resilient educators capable of handling diverse classroom challenges.

Mathematical thinking is an important aspect of learning, so it needs to be placed as the main learning goal (Ferdianto et al., 2022). By knowing the ability to think mathematically, students can be better prepared to face mathematical problems. Students' in-depth understanding of mathematical concepts can encourage the development of logical thinking skills so that they can represent most of students' skills in studying at the basic education level (Sitopu, 2024). Furthermore, the lack of teachers' habits in implementing numerical literacy in school results in students experiencing difficulties when solving numeracy problems (Sayekti et al., 2022). The lack of teachers' ability to teach numeracy problems results in a lack of student understanding, so it is necessary to produce prospective teacher students who are able to teach numeracy problems.

If you see the phenomenon of teachers' difficulties in teaching numeracy problems, it is necessary to produce prospective teacher students who can teach how to solve numeracy problems. The difficulties of prospective teacher students in solving numeracy problems can be identified through adversity quotients. The results of the study stated that students' persistence or effort in solving mathematical problems can be identified through three types of adversity quotients. Each type of AQ student has a different response to mathematical problems (Nikam & Uplane, 2013; Triwahyuningtyas et al., 2023). Students with high AQ types are more proficient in solving problems compared to students with medium AQ and low AQ types (Anwar et al., 2024). Students with medium AQ and low AQ categories are more likely to give up when facing math problems that are considered difficult. Other research also shows a link between adversity quotient and metacognition because both are related to students' thinking activities in solving problems (Jemina et al., 2022).

The results of research in the last ten years show that not many have studied students' mathematical thinking activities in solving numeracy problems (Chang, 2023; Ferdianto et al., 2022; Hariyani et al., 2022; Hwang, 2020; Okigbo & Okonkwo, 2023; Purnomo et al., 2022; Sitopu, 2024). The research discusses the development of numeracy problems, so it is necessary to conduct research on the exploration of mathematical thinking activities of prospective teacher students so that there are no more graduate students who are prospective teachers who experience difficulties when teaching numeracy problems. Therefore, this study aims to explore the mathematical thinking activities of prospective teacher students in solving numeracy problems reviewed from Adversity Quotient.

LITERATURE REVIEW

Mathematical thinking frameworks based on Mason's (2010) are specialising-generalising-conjecturing-convincing model, can be effectively integrated with AQ to better understand how perseverance manifests in specific cognitive stages. For instance, students with climber-type AQ are likely to persist through conjecturing and convincing, while quitter-type students may disengage after initial specialising attempts. This integrative approach opens new avenues for teacher education research, emphasising both cognitive and non-cognitive factors in numeracy teaching.

Adversity Quotient (AQ) is defined as the persistence of students in overcoming obstacles faced to achieve the desired success (Nikam & Uplane, 2013; Suryadi & Santoso, 2017). The quitter type is the type of student who tries to escape from problems. Quitter students find math complicated and confusing, so they have no motivation to solve problems. The camper type is a student who does not want to take risks, so he feels satisfied with the situation that has been achieved so far. While the climber type is a student who has a target so that he is tenacious and persistent to be able to achieve the desired target. Climber students have courage and discipline. In terms of learning mathematics, students with the *climber* type feel happy to learn mathematics because they feel challenged (Amir et al., 2021). Each type of adversity quotient is closely related to a person's ability to think in overcoming difficulties (Jemina et al., 2022).

The persistence of students in solving numeracy problems is inseparable from their mathematical thinking skills. Mathematical thinking is an ability that students must have in order to build knowledge when solving mathematical problems (Çelik & Özdemir, 2020). Students' mathematical thinking skills can be built through the process of assimilation and accommodation. Assimilation is the process of incorporating new information into an existing scheme. Meanwhile, accommodation is the process of adjusting the scheme that already exists in the student's brain with a new scheme (Faizah et al., 2022a). Students can carry out assimilation and accommodation processes to construct their knowledge. Mathematical

thinking is also carried out through students' cognitive activities that can be observed through written and spoken language, arithmetic symbol operations, and axiomatic formal symbols (Rahayuningsih et al., 2021).

The ability to think mathematically needs to be possessed by every student, especially prospective elementary school teachers. This is because mathematical thinking is a provision to become a professional educator and is ready to become the best facilitator in mathematics learning in schools, especially in elementary schools (Tohir et al., 2020). Mathematical thinking starts from the experience of several phenomena that can trigger questions (Mason, 2010). Mathematical thinking skills can be known through the process of abstraction, synthesis, generalisation, modeling, problem solving, and verification (Tall, 2002; Yorulmaz, 2017). Furthermore, Mason (2010) mentioned that mathematical thinking skills are carried out through several stages, namely: entry, attack, and review. Each of these stages contains several aspects. At the entry stage, it contains know, want, and introduction.

Students understand the problem carefully by grouping and sorting out information. Then in the attack stage there are try, maybe, and why. Students submit conjectures and then try these conjectures to solve the problem. Meanwhile, the review stage contains aspects of check, reflect, and extend. Students check the accuracy of the results of problem solving. In addition to these three stages. Mason (2010) also mentioned that in identifying students' mathematical thinking skills, there are four important processes. First, Specialising is the stage of specialising in problems such as making a pattern or picture and arranging parts of the problem such as what is known and what is asked. Second, generalising is the activity of looking for solutions and how to test the truth steps of an alleged solution. Third, conjecturing is the activity of making conjectures from patterns or methods that have been made. The conjectures that have been made are tested for truth and if the conjecture is wrong, a new conjecture must be made until the right solution is found. Fourth, convincing is students' confidence in the results of problem solving. This belief can be shown by explaining each completion step that has been carried out based on the numeracy concepts that students understand.

The four stages of mathematical thinking are closely related to the Adversity Quotient because it is to find out the persistence of prospective elementary school teacher students in solving numeracy problems. If mathematical thinking ability is known, it is hoped that students will not experience problems when solving numeracy problems. If there are still students who experience problems, it is necessary to provide scaffolding. According to Faizah et al. (2022b), the provision of scaffolding can be done by more expert people, in this case it can be colleagues or lecturers. In this study, the exploration of students' mathematical thinking activities from each type of adversity quotient was identified based on four important processes, namely

specialising, generalising, conjecturing, and convincing.

Research on AQ demonstrates strong correlations with academic achievement, motivation, and resilience across disciplines. Stoltz (1997), who originally coined the concept, emphasised that individuals with high AQ are more likely to transform obstacles into opportunities, a quality that resonates strongly within mathematics education. Comparatively, Duckworth's notion of grit and Bandura's concept of self-efficacy share similarities with AQ, but AQ uniquely emphasises the behavioural responses to adversity. This makes it particularly relevant for mathematical problem solving where frustration and cognitive disequilibrium are common experiences.

In the Indonesian context, research linking AQ to numeracy is still emerging. Studies have shown that students with high AQ demonstrate stronger problem-solving persistence, greater metacognitive awareness, and a tendency to engage in higher-order reasoning strategies. Moreover, AQ has been linked with socio-cultural aspects of learning, as collectivist cultures often emphasise communal resilience and perseverance. Prospective teachers, therefore, need explicit opportunities to develop their AQ through problem-based learning, reflective practice, and scaffolded experiences in teaching numeracy.

Cultural values significantly shape how adversity and resilience are perceived in educational contexts. In collectivist societies like Indonesia, perseverance is often framed in terms of communal responsibility and respect for teachers. Students may persist not only for personal success but also to uphold family expectations or contribute to group achievements. This contrasts with more individualist cultures, where resilience is often viewed as personal grit or self-determination. Recognising these cultural nuances is critical for developing AQ interventions that are culturally responsive and contextually relevant.

Moreover, Indonesian educational traditions emphasise moral and character education, which aligns well with AQ development. Embedding AQ in this context does not require importing foreign concepts to wholesale but rather adapting them to local values. For example, the concept of mutual cooperation (*gotong royong*) can be harnessed to frame perseverance as a shared classroom responsibility. Such cultural grounding ensures that AQ development is meaningful, authentic, and sustainable.

METHODS

This study followed rigorous ethical and methodological protocols. Prior to data collection, ethical clearance was obtained from the institutional research committee, ensuring compliance with confidentiality, informed consent, and voluntary participation. Participants were briefed on the aims of the study and assured that pseudonyms would be used to protect their identity.

The AQ questionnaire was validated through expert judgment involving specialists in mathematics education and

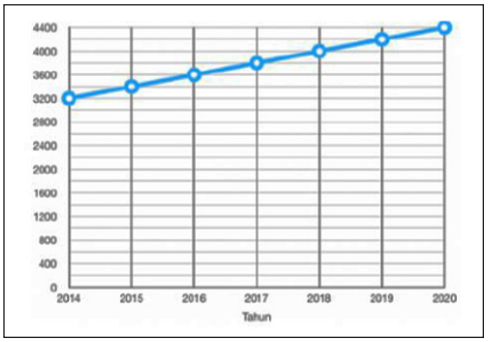
educational psychology. Reliability was tested using Cronbach's Alpha, producing a coefficient of 0.82, which indicates strong internal consistency. The numeracy problem test underwent pilot testing with 10 students outside the research sample to refine the clarity of instructions and graphical representations. Semi-structured interview protocols were also peer-reviewed to ensure alignment with the research objectives. For data analysis, coding procedures were carried out iteratively. Open coding was applied to initial transcripts, followed by axial coding to establish connections between AQ types and stages of mathematical thinking. Triangulation was achieved by comparing written tests, interview responses, and researcher observations. Inter-rater reliability was enhanced by involving two independent coders who cross-checked emerging themes. The resulting data corpus was then subjected to thematic interpretation guided by Creswell's (2014) framework.

This research is included in the type of exploratory descriptive with a qualitative approach. This research was conducted on forty prospective teacher students who are taking the Basic Mathematics Education and Concepts Course in the Elementary School Teacher Education Study Programme. The selection of research subjects was carried out using an *adversity quotient* questionnaire to classify students. From each type of *adversity quotient*, two students were selected to be the subject of research so that there were six students who would be given a written test on numeracy problems. Students who have been selected as research subjects and have completed the test will be interviewed in depth to explore their mathematical thinking activities.

The instruments used in this study are numeracy problem tests, *adversity quotient* questionnaires, and interviews. The researcher conducts the instrument validation process to the expert validator before the instrument is given to the student. During the interview process, the researcher recorded using a video *tape recorder* to facilitate the transcript process. The interview was used to explore the mathematical thinking activities of the research subjects when completing a numeracy problem test. The test instruments used in this study are presented in Figure 1.

The research procedure is carried out through four stages. In the first stage, the researcher made observations during the

Written Test:
There is a clothing factory called "the companies of like to prosper". The factory started producing clothes in 2014 with a lot of production as in the following table:



How many apparel will the " the companies of like to prosper" factory produce in 2024?

Figure 1. Written test

lecture process in the course "Education and Basic Concepts of Mathematics." In the second stage, the researcher gave an adversity quotient questionnaire to determine the research subject. In the third stage, the researcher gave a numeracy problem test to students who had been selected as research subjects. In the last stage, the researcher conducted in-depth interviews with research subjects to explore their mathematical thinking activities.

The collected data is then analysed using qualitative data analysis techniques from Creswell (2014) which contain three stages, namely: data reduction, data interpretation, and conclusion. Data reduction is the selection of data based on suitability with the research objectives. Meanwhile, data that are not in line with the research objectives are considered as findings. The data that has been reduced is then described as it is according to the results of research in the field. The last step is to make a conclusion based on the results of data interpretation. In this case, data analysis about students' mathematical thinking processes is based on several stages: Specialising, Generalising, Conjecturing, and Convincing.

RESULTS AND DISCUSSION

Climber students do not give up easily when they get problems that require mathematical and analytical thinking skills. They continue to try to understand every piece of information and questions presented in the questions. Students with this type still try to solve problems that other students think are quite difficult. Meanwhile, *camper* students seem to have made less effort in identifying every information presented in the questions so that the answers given are not appropriate. Camper students are quickly satisfied with the results obtained, so they do not check again. Then students with *quitter* type work on the problem without any effort so that they are stuck as long as they are finished. *Quitter* type students do not identify problems first but immediately give answers that are not in accordance with the questions in the question. In general, the percentage of students who are prospective elementary school teachers is reviewed from the type of *adversity quotient* presented in Figure 2.

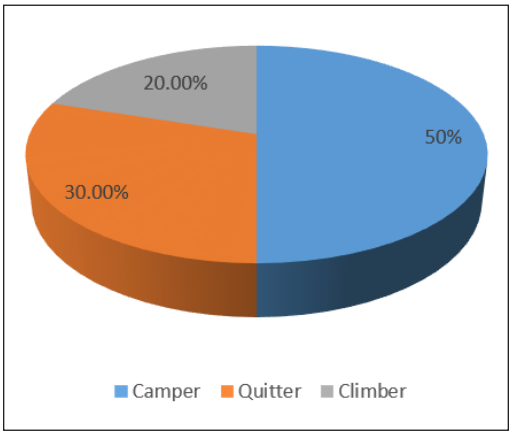


Figure 2. Adversity Quotient test results

Figure 2 shows that there are more students with *camper* and *quitter* types than *climber* type students. The researcher randomly selected student representatives from each type to be used as research subjects. The researcher uses a pseudonym to explain the results of the exploration of each research subject.

Climber Type Students

The findings reveal nuanced differences across AQ types that extend beyond initial expectations. Climber-type students not only demonstrated persistence in problem solving but also displayed positive affective behaviours such as enthusiasm, curiosity, and willingness to explain their reasoning to peers. This aligns with international findings that suggest high-AQ students are more likely to embrace productive struggles in mathematics.

Aldo is a pseudonym for students who are researching subjects with a climber type. He gave the correct answer to the question he was working on. Aldo answered the question by identifying each information contained in the question. The identification carried out is to determine how much the number of clothing production increases every year. Aldo said that the increase in the number of productions every year is 200 clothes. The last information presented in the question is the amount of production in 2020, while what is asked is 2024, so the difference is 4 years.

Thus, Aldo can conduct an analysis to calculate the number of clothes produced over 4 years is 800 clothes. Furthermore, Aldo used the information known in the question which stated that the production in 2020 was 4,400 clothes and then added it up with 800 clothes so that the production in 2024 was 5,200 clothes. This was not written directly by Aldo but was conveyed during an in-depth interview between the researcher (R) and the subject Aldo (SA) to him, as shown in the following interview snippet:

R : Why can 4,400 be added by 800? Where can you get 800 from?

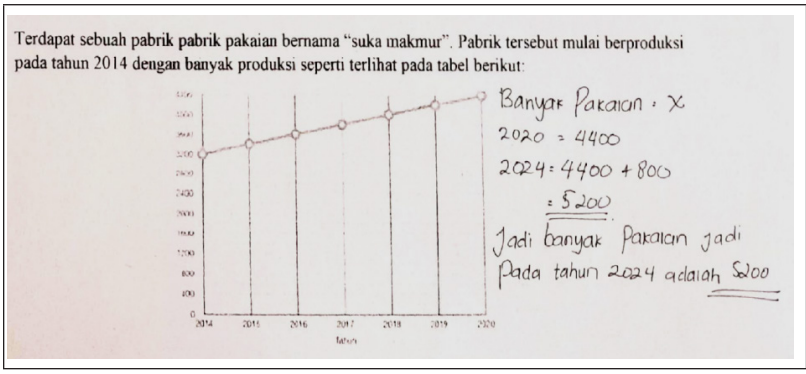
SA : Many clothing productions in 2024 are not yet known, but in 2020 it is already known, namely 4,400 clothes. Because the increase every year is 200 clothes, to find out the increase in production from 2020 to 2024 is $200 \times 4 = 800$, I multiply by 4 because from 2020 to 2024 there is a difference of 4 years. After that, to find out the number of productions in 2024, I just need to add 4,400 by 800 so that 5,200 clothes are obtained

The interview was conducted in depth to Aldo as a subject with the Climber type. The interview is based on the results of a written test that has been done by the Climber subject. The results of the subject's work are presented in Figure 3.

From the results of the exploration to the subject, Aldo is known that he carried out thinking activities for *the specialising* stage by identifying the information presented about the increase in the number of clothes produced every year, which is as many as 200 clothes. Then he *generalizes* by determining the amount of production between 2020 and 2024. The *conjecturing* stage is carried out by mentioning the number of fabrics produced into clothing in 2024 as many as 5,200. The last is the *convincing* stage by providing an explanation of the results of making conjectures.

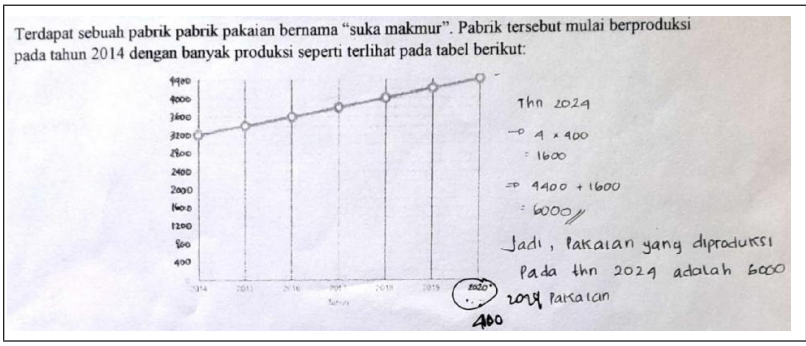
Camper Type Students

Camper-type students, while making an effort to engage with problems, revealed



There is a clothing factory called "Suka Makmur." The factory started producing clothes in 2014 with a lot of production as in the following table:
Lots of clothes = x
2020 = 4400
2024 = 4400 + 800
= 5200
So, the number of clothes in 2024 is 5200

Figure 3. Climber type students' work



There is a clothing factory called "Suka Makmur". The factory started producing clothes in 2014 with a lot of production as in the following table:
2024
4 × 4400 = 1600
4400 + 1600 = 6000

So, the clothes produced in 2024 are 6000 clothes

Figure 4. Camper type students' work

tendencies toward cognitive bias, particularly in misinterpreting graphical data. Their pseudo-generalisations stemmed from overreliance on surface features of problems rather than deeper structural reasoning. This suggests that interventions for camper-type students should emphasise critical reading of mathematical representations and guided reflection on error analysis.

Bety is a pseudonym for students with *a camper type.* Bety mentioned that the "Suka Makmur" factory produced clothes in 2014, 2015, 2016, 2017, 2018, 2019, and 2020. Every year the factory experiences an increase of 400 clothes, then the difference from 2020 to 2024 is four years so that the production of clothes in a period of 4 years is 1,600 clothes. Then, to determine the number of clothes in 2024, Bety added up the number of clothes produced from 2020 to 2024 so that 6,000 clothes were obtained. The results of the *camper* type of subject work can be seen in Figure 4.

From the results of the work of the subject Bety, it is known that he carries out *specialising* activities by identifying the increase in clothing production every year. From the results of the identification, information was obtained that the increase in the number of clothing production every year was 400 clothes. Then, for the *generalising* stage, it is carried out

by determining the amount of clothing production between 2020 and 2024. From the *results of generalising*, it was obtained that a lot of clothing production from 2020 to 2024 is 1,600 clothes, so the *conjecture* formed by Bety is a lot of clothing production in 2024 as many as 6000 clothes.

This was conveyed by Bety during an interview, but the explanation conveyed was not appropriate because he mentioned that the increase in production every year was 400 clothes instead of 200 clothes. This happened because Bety was not aware that he was not careful in reading the graph presented in the test questions. The result of Bety's work is the same as another student who is also a camper type. The student is named Norma because she also gave an answer of 6,000 clothes, even though the correct answer was 5,200 clothes. The inaccuracy of students in reading graphs can be categorised as *pseudo-generalisation*. The term *pseudogeneralisation* is in accordance with the opinion of Dumitrascu (2017) which states that the process of generalisation in mathematical thinking can be carried out pseudo-generalisation. In this case, the subject makes generalisations based on incorrect data.

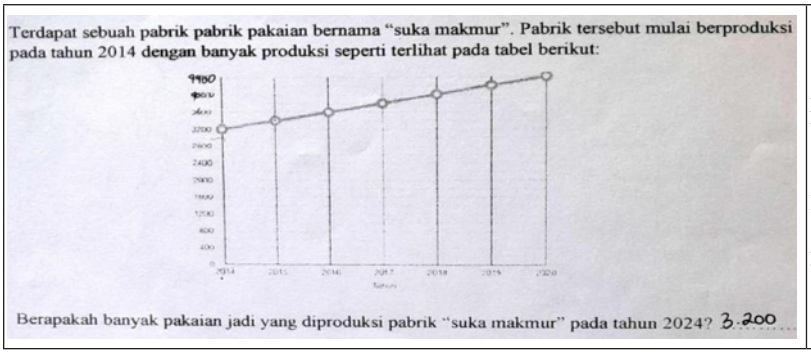
Quitter Type Students

Quitter-type students' disengagement underscores the urgent need for targeted scaffolding strategies. Their responses reveal limited self-efficacy and a lack of resilience, which may be linked to previous negative experiences in learning mathematics. Embedding growth mindset training, affective support, and incremental task design into teacher education programmes may help mitigate these tendencies.

Cindy is a pseudonym for Quitter-type students who are the subject of research. Cindy only identified the problem by looking at the number of clothes produced in 2014 because she assumed that the number of clothes produced in 2024 would be the same as in 2014, which was 3,200 clothes. Thus, it can be seen that Cindy did not do the *generalising* and *convincing stage,* because she only gave answers in the form of assumptions based on the information written in the question. Cindy did not conduct a more in-depth analysis of each information presented in the question. Cindy's mistakes in doing the test can occur because she is not able to identify all the information presented in the form of a graph. The results of Cindy's work are presented in Figure 5.

From the results of the exploration to the subject, Cyndi shows that he has no effort to understand every piece of information presented in the question. As a result, not all stages of mathematical thinking activities are carried out by Cyndi. Then the answers obtained from the results of solving the problem are not in accordance with the questions contained in the questions. This can be seen from the results of an interview conducted by the researcher (R) with SC (Cyndi's subject).

R : Where can you get 3200 for clothing production in 2024?
SC : I equate it with the number of productions in 2014, ma'am.
R : Why are they equated?
SC : Because my assumption is the same between 2014 and 2024



There is a clothing factory called "Suka Makmur". The factory started producing clothes in 2014 with a lot of production as in the following table:

How many apparel will the "Suka Makmur" factory produce in 2024? 3.200

Figure 5. Quitter type students' work

Based on the analysis of the results of student work on each type *of adversity quotient*, differences in mathematical thinking activities were obtained. These differences are presented in Table 1.

Table 1
Student thinking activities

Observed Variables	Type	Mathematical Thinking	Indicators	Descriptor
Adversity Quotient	Climber	Specialising	Identify the information presented in the question	Mentioning the increase in clothing production every year
		Generalising	Determining the settlement steps to make a guess	Clothing production within four years as many as 800 clothes
		Conjecturing	Giving a conjecture	The number of clothing production in 2024 will be 5,200 clothes
		Convincing	Providing an explanation of the results of the allegations	The explanation conveyed was precise and appropriate.
	Camper	Specialising	Identify the information presented in the question	Observing the increase in many clothing productions every year
		Generalising	Determining the settlement steps to make a guess	Clothing production within four years as many as 1,600 clothes
		Conjecturing	Giving a conjecture	The number of clothing production in 2024 will be 6,000 clothes
		Convincing	Providing an explanation of the results of the allegations	The explanation presented was incorrect because there was an error in identifying the data at the generalisation stage
	Quitter	Specialising	Identify the information presented in the question	Only focus on the production of clothing in 2014
		Generalising	Determining the settlement steps to make a guess	Not doing
		Conjecturing	Giving a conjecture	Clothing production in 2024 is the same as production in 2014
		Convincing	Providing an explanation of the results of the allegations	Not doing

From Table 1, it is known that not all students from each type of adversity quotient do the stages of mathematical thinking. The inability of students to do mathematical thinking stages is due to students not being used to solving numeracy problems related to reading graphs. The *specialising* stage carried out by Aldo and Bety is in accordance with what was conveyed by Putri et al. (2020) that in *specialising* contains three activities, namely: students can compile details of the information known and asked in the question; students can understand concepts based on past experience to solve problems; students can find examples related to some information on the problem being solved.

Generalisation is an activity to determine information that applies in general. Generalisation is defined as a statement that is considered correct for all categories of objects in the question (Dumitrascu, 2017). Generalisation can also be interpreted as the relationship between objects in a set and subsets. In other words, generalisation is expanding the object of the mathematical set being worked on by identifying the general information in the set (Jeannotte & Kieran, 2017). Problem identification in mathematical thinking can also be characterised by reading the question carefully, determining relevant ideas, classifying ideas into several objects, representing them in the form of notation or symbols (Faizah et al., 2020). In this case, generalisation is manifested by the ability of prospective elementary school teacher students when determining a large increase in clothing production in 2024 based on the information available on the graph.

Generalisation is closely related to conjectures because generalisation is a way to formulate conjectures (Santos et al., 2022). Conjecture is the process of formulating a claim accompanied by complete evidence. The evidence of a conjecture is built through a mathematical thought process to form a valid argument (Pedemonte, 2008; Sa'adah et al., 2023). Furthermore, conjecture is a mathematical statement that is hypothetical, that is, the statement has the potential to be true because it is constructed by students using their own knowledge based on the information contained in the problems that have been worked on (Astawa et al., 2018). In this case, conjecture is an allegation in the form of a statement of the research subject based on the results of generalisation.

The statements given by the subject can be true or false. The results of the exploration to Aldo's subject show that the conjecture given is true so that the answer given is also correct. Meanwhile, the subject Bety gave a wrong guess because he made a mistake when identifying the information written in the question. Meanwhile, *convincing* is the stage of providing an explanation of the conjecture that has been given. In this case, not all types of adversity quotients carry out the stages of mathematical thinking because of the limitations of students in identifying every information presented in the problem so that they do not do the convincing stage.

The implications of these findings are manifold. For teacher education, it is essential to design curricula that not

only teach mathematical content but also explicitly nurture resilience and perseverance. Policymakers can also draw from these insights to align national curricula, such as *Merdeka Belajar* and AKM, with initiatives that integrate non-cognitive skill development. From a research perspective, the integration of AQ and mathematical thinking offers a promising interdisciplinary framework for advancing mathematics education scholarships.

Case Examples and Classroom Narrative

To better illustrate how AQ manifests in real classrooms, consider a prospective teacher facing a class of students struggling with a numeracy problem involving fractions. A quitter-type teacher may avoid delving deeper into the concept, offering superficial explanations and quickly moving on to avoid discomfort. A camper-type teacher might attempt a solution but rely heavily on procedural drills, failing to address underlying misconceptions. In contrast, a climber-type teacher would persist, experimenting with visual aids, encouraging peer discussion, and re-explaining concepts until students grasp the material. These narratives highlight the direct pedagogical consequences of AQ in shaping classroom dynamics and student learning outcomes.

Another example involves graph interpretation tasks, similar to those used in this study. When confronted with a graph depicting production increases, quitter-type students tend to default to guesses, while camper-type students misread the increments. The climber-type students, however, systematically analysed the trend and cross-checked their conjectures, ultimately producing accurate answers. Embedding such case studies into teacher training can help prospective teachers self-reflect on their own AQ tendencies and adopt strategies to strengthen persistence.

Comparative international research underscores the urgency of strengthening numeracy and resilience. In countries such as Finland, Singapore, and Japan, numeracy education is tightly linked with practices that encourage persistence and problem-solving. Finnish schools integrate collaborative problem-solving tasks, which not only deepen numeracy skills but also build adaptive social-emotional competencies. In Singapore, the 'productive struggle' approach is institutionalized, where students are deliberately exposed to challenging problems with structured teacher support. This pedagogical culture normalizes mistakes as opportunities for growth and builds both cognitive and non-cognitive resilience.

Japan's lesson study model provides another lens through which AQ can be nurtured. Teachers collaboratively plan, implement, and reflect on lessons, often focusing on difficult problems that stimulate deep thinking. Such collective reflection fosters not only teacher professional growth but also resilience in navigating challenging classroom dynamics. By drawing lessons from these global models, Indonesian teacher education can integrate best practices to enhance AQ development among future elementary school teachers.

In the era of digital transformation, technology can play a critical role in supporting AQ development. Adaptive learning platforms can personalize numeracy challenges according to students' persistence levels, providing gradual scaffolding for those who tend to give up early. Gamification elements, such as badges for persistence or progress milestones, can encourage sustained engagement. Augmented reality (AR) and virtual reality (VR) tools may also immerse students in authentic problem-solving environments where resilience is naturally demanded.

For teacher education, incorporating digital tools into numeracy pedagogy courses can simulate real-life adversity. For example, simulation-based platforms can create scenarios where teachers must respond to student errors, classroom disruptions, or conceptual misconceptions. These simulations can serve as safe practice grounds for building AQ, as they allow repeated attempts, feedback, and reflection. Thus, integrating technology not only strengthens numeracy teaching but also cultivates adaptability and resilience among future teachers.

Comparing international education policies provides valuable lessons for embedding AQ in teacher education. In Australia, professional standards for teachers emphasise resilience and adaptability as part of graduate attributes. In the United States, social-emotional learning frameworks highlight perseverance and grit as essential for student success, indirectly influencing teacher preparation. Meanwhile, countries like Finland integrate resilience training into teacher induction programmes, ensuring that novice teachers develop coping strategies during their first years in the profession.

Indonesia's current reforms under Merdeka Belajar can draw from these global precedents. Explicitly positioning AQ within national teacher competency standards would not only strengthen teacher preparation but also align with the country's broader educational vision. Embedding AQ into teacher certification, professional development, and school evaluation systems could institutionalize resilience as a key quality for both teachers and students. By doing so, Indonesia would contribute to global conversations on education reform while addressing local challenges in numeracy teaching.

Looking ahead, teacher education must evolve to prepare future educators who are not only content experts but also adaptive, resilient, and globally aware. Future-oriented teacher education models emphasise interdisciplinary integration, digital literacy, and lifelong learning dispositions. Programmes should be designed to expose prospective teachers to complex, real-world problems that require persistence, collaboration, and innovation to solve. By embedding these experiences early in teacher preparation, institutions can ensure that future teachers enter the profession with both strong mathematical competencies and the resilience to navigate the uncertainties of modern classrooms.

Several emerging models illustrate these principles. For instance, transdisciplinary problem-based learning (PBL) approaches integrating numeracy with science,

technology, and social studies, encouraging students to apply mathematical reasoning across contexts. In such environments, adversity is inevitable, and students must cultivate AQ to manage ambiguity and complexity. Another model involves digital micro-credentialing, where prospective teachers earn badges for demonstrating resilience in teaching practicums, reflective practice, or mastery of AQ-related competencies. These innovations suggest that AQ can be operationalised as a measurable outcome in teacher education.

To ensure the practical impact of this research, comprehensive recommendations are outlined across multiple levels. For teacher educators, AQ-focused reflective tasks should be mandatory in numeracy courses, supported by continuous feedback mechanisms. For policymakers, national teacher standards should explicitly integrate non-cognitive skills, with AQ identified as a measurable competency. For curriculum designers, numeracy modules should include open-ended problems, case studies, and group projects that encourage persistence and adaptive reasoning. At the school level, professional learning communities (PLCs) can be leveraged to create peer support systems where teachers share strategies for overcoming numeracy teaching challenges. Additionally, assessment reforms should recognise not only mastery of content but also perseverance in approaching complex problems. Collectively, these recommendations provide a roadmap for embedding AQ into Indonesia's broader educational reform agenda.

CONCLUSION

Adversity Quotient is closely related to mathematical thinking skills. There are three types of Adversity Quotient for prospective elementary school teachers in solving Numeracy problems. The mathematical thinking activity of each type of Adversity Quotient is explored through four stages, namely specialising, generalising, conjecturing, and convincing. Climber type teacher candidates do all four stages of mathematical thinking correctly when solving numerical problems. Camper type students also carry out the four stages of mathematical thinking, but at the generalising stage, students are not thorough. This is because students are unable to identify the data presented in the form of graphs so that camper type students experience *pseudo-generalisation*. While *quitter* type students only do *the specialising* and *conjecturing stages,* quitter type students do not do the generalising and convincing stages because of their limited ability to identify every information presented. From the results of the study, it was found that quitter type students did not do all stages of mathematical thinking because students did not identify every information presented in the form of graphs and did not often practice solving numeracy problems.

Practical implications include embedding AQ development into teacher preparation curricula through problem-based learning, reflective journals, and collaborative teaching simulations. Future research could adopt longitudinal designs to track AQ development over time, as well

as cross-cultural comparisons to investigate the universality of AQ's impact on numeracy problem solving. Furthermore, experimental studies test specific pedagogical interventions—such as metacognitive training or growth mindset workshops—could provide actionable strategies for educators. Ultimately, preparing resilient, reflective, and numerate teachers will contribute significantly to improving mathematical literacy and lifelong learning outcomes in Indonesia and beyond. By expanding the scope of this study, the article now offers both theoretical enrichment and practical pathways for strengthening teacher education in the 21st century.

In conclusion, the integration of Adversity Quotient into teacher education is not only a theoretical aspiration but also a practical necessity. As the global landscape of education becomes more uncertain and complex, resilience and persistence emerge as critical attributes for both teachers and students. This study contributes by linking AQ with mathematical thinking, offering evidence that resilience directly impacts how future teachers engage with numeracy problems. Expanding this discourse can inspire innovations in pedagogy, curriculum, and policy that ensure education remains relevant, equitable, and empowering for all learners.

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Analytical Review on Socio-Psychological Analysis of the Fast Track Policy in Primary Education

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ABSTRACT

Providing educational centres responsive to children's potential and individual needs is critical in developing their overall growth and improving their academic success. Accelerated education provides space and ease for intellectually gifted children to enhance their educational achievement. The findings of this study indicate that the implementation of acceleration policies has various impacts on students' social and psychological development, particularly their emotional well-being. Positive effects are the improvement in self-concept, self-esteem, attitude towards academics, motivation, self-confidence, and career plans. Additionally, acceleration policies can have academic gains and improve the social and emotional adjustment of students. On the other hand, findings on the effects of acceleration programmes indicate that they will have no noticeable impact on social development or even be neutral, particularly in the area of students' ability to make friends. Contrarily, evidence points to the flaws in accelerated policy execution lying within student's problems of interaction with their age mates via the lack of enough time to socialise. This is because they are weighed down by academic loads. The chances of accelerated students losing opportunities for developing their leadership skills through believing they belong among their age group classmates are high.

Keywords: Elementary education, fast-track, psychology, social

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INTRODUCTION

Providing educational infrastructure that is appropriate for the potential and needs of children is necessary for their growth and success in school. By the understanding and accommodation of the unique gifts, interests, and learning styles of each child, education can offer an environment that supports their strengths and helps them

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improve their weaknesses (Howitt, 2019; Mishra, 2013). Education should therefore provide infrastructure that allows children to be instructed based on their capabilities. This would translate to children being given personalised learning, one-on-one care, and avenues for discovery and achievement in fields where they are talented or interested.

Education also needs to include inclusivity and diversity by providing for the diverse needs of disabled, culturally diverse, or diversely capable students. By providing a range of educational resources, adaptive technology, and special programmes, school buildings can ensure all children are given an equal chance to high-quality education (Delahunty & Kimbell, 2021). Additionally, adequate classrooms, appropriate learning materials, and facilities to enable physical education and experiential learning are important to provide the optimal learning environment. In conclusion, giving a priority to providing education facilities that are built to be responsive to children's potential and needs is central to facilitating their development, to inclusivity, and to ensuring that all children are capable of achieving their full potential (Santika et al., 2021).

Quality education ought to promote the application of individuality in each child and promote the application of student-centred learning where their weaknesses and strengths are valued and respected (Khalafov, 2021; Tulasi & Rao, 2021). This way, children are supposed to academically, socially, and emotionally thrive since their learning experience is tailored to their specific needs and abilities. Additionally, there is also a need to provide inclusive and accessible educational infrastructure so that the special needs of children can fully reap the benefits of the learning process (Irvan & Jauhari, 2018). Intellectually gifted children, possessing above-average intellectual intelligence, are one such group of special needs children.

Students who have greater than average intellectual ability require special attention regarding education. Offering educational institutions with infrastructures that cater to their potential or special needs is crucial to ensure their maximum development and academic success. These students have special abilities and require customised education programmes to challenge and improve their intellectual potential (Demchenko et al., 2021; Suherman, 2014). By offering a differentiated and enriched curriculum, special schools or programmes for gifted students can provide them with intellectual stimulation and academic challenges at an appropriate level. This personalised approach not only enables children to achieve their full potential but also enables them to develop a sense of belongingness and positive self-image

Among the services offered under formal education is the acceleration of talented children through the provision of accelerated or fast-track class programmes in schools. These are especially for students who have high intellectual intelligence (IQ) or high talent. The goal is to provide an accelerated curriculum and learning experience to high-ability students in

grade school (S. Chandrasekhar & Laily Noor Ikhsanto, 2020). The acceleration programme is tailored to meet the educational requirements of possibly gifted and/or exceptional talent students so that they may complete normal programmes in a shorter time than their non-participating peers. This would mean completing elementary school in 5 years and junior high or senior high school in 2 years. In practice, all uses of acceleration programmes are accompanied by enrichment programmes that provide additional learning time to further extend and deepen their knowledge (Directorate of Special Schools Development, 2011). Education acceleration programmes attempt to condense the learning chances of students with gifted abilities.

Such students are empowered through the programmes to progress faster, acquire knowledge over and above their current curriculum, and receive assistance tailored to their needs and interests. Not only do such programmes offer academic benefits by enabling high-ability students to outperform their peers, but they also have a positive impact on their social and emotional development (Duan et al., 2010). Through interactions with intellectual peers and challenging tasks, fast-track programmes enable students to feel a sense of belonging and provide a supportive learning environment for gifted students. Fast-tracking in education can be a beneficial option for high-ability students. It helps them learn faster, stretches them academically, and prevents boredom or complacency in class.

By offering advanced classes or accelerated programmes, instructors are able to meet the demands of gifted students and offer the perfect learning environment that supports their intellectual development. Additionally, fast-tracking education helps students gain valuable skills such as time management, resilience, and critical thinking. Accelerated educational programmes give talented students the opportunity to delve further into their subject of interest and accelerate their studies (Duan et al., 2010; Steenbergen-Hu & Moon, 2011).

Children who are placed on the fast track are typically those with a high IQ or strong intellectual abilities. Accelerated programmes focus primarily on cognitive and academic skills, placing less emphasis on social and psychological development. Therefore, it is important to thoroughly examine how the fast-track approach impacts the psychological and social development of children, particularly at the elementary school level. This article aims to delve deeper into four main aspects: (1) the concept of fast track or acceleration; (2) the legal and policy foundations of fast track in basic education; (3) the implementation of fast track in basic education; and (4) the social and psychological development of students in fast-track programmes at the basic education level.

The urgency of conducting research on the socio-psychological analysis of fast-track policies in basic education through the SLR approach is very high because this policy has a broad impact on

students' psychological development, social equality, and the effectiveness and fairness of the education system. With a systematic approach, the results of this research can be an important reference in formulating policies that are more targeted and based on strong scientific evidence

This study makes a distinctive contribution to the existing body of literature in several important ways. First, it is among the first to systematically examine the socio-psychological impacts of fast-track policies specifically at the primary education level within the Indonesian regulatory context, using a structured Systematic Literature Review (SLR) approach encompassing articles published from 2014 to 2024. Second, unlike previous reviews that tend to focus exclusively on academic outcomes or general well-being, this study integrates legal-policy analysis with socio-psychological impact assessment—a dimension that has been underrepresented in prior scholarship. Third, by synthesising 30 carefully selected articles under a three-dimensional analytical framework (positive, neutral, and negative socio-psychological impacts), this review offers a more nuanced and structured picture of the consequences of fast-track education than what is currently available in the literature. These features collectively strengthen the originality and practical relevance of the present study.

LITERATURE REVIEW

The presence of education institutions that are responsive to potential and needs of students offers a core basis for pursuing quality and equitable education. Research shows that learning environments that are responsive to children's learning style, interest, and ability can best assist learners' academic growth and emotional growth as well (Howitt, 2019; Mishra, 2013). To this effect, education needs to facilitate individualised approaches that adopt the diversities of the learners, i.e., special children and gifted learners. Such education for diversity and inclusivity not only brings out the greatest possible academic achievements but also promotes students' confidence to feel closer to and be a part of the learning fraternity (Delahunty & Kimbell, 2021).

One type of student to be treated differently is higher-than-average intellectual capacity for students. Such students need instruction services that stimulate and engage their intellectual potential to the fullest (Demchenko et al., 2021). Acceleration programmes have been documented through research to be an effective way of meeting the educational needs of gifted children (Steenbergen-Hu & Moon, 2011). These programmes grant students the power to attain education levels in a shorter time frame and to learn learning content at a higher level that is conducive to their capacity. Besides facilitating scholastic growth, acceleration programmes also nurture important skills such as time management, intellectual judgment, and autonomy in learning (Colangelo et al., 2004; Duan et al., 2010).

However, there are certain studies that highlight that the use of acceleration

programmes primarily focuses on cognitive development and not much on students' social and emotional development (Worrell et al., 2019). Gifted students who are taking acceleration programmes often struggle with social adjustment, especially if they are not in an environment where they have the opportunity to interact with peers at the same developmental level. Therefore, academic acceleration plans need to be balanced with plans fostering students' psychological well-being and social competence as well (Kulik & Kulik, 2004).

In Indonesian policy on education, acceleration programmes have been regulated as a form of extraordinary educational service for students with high ability, according to Ministerial Regulation No. 70 of 2009 and the Directorate for Special Education guidelines (Directorate of Special Schools Development, 2011). Nevertheless, implementation of such programmes is most often confronted with hindrances, including difficulties in establishing student selection criteria, teacher preparedness, and providing appropriate curricula. Thus, a systematic review of acceleration policy socio-psychological impacts is called for to promote more holistic and equitable implementation

METHODOLOGY

The method used in this article is a literature study, which is secondary research to find, assess, and interpret all evidence relevant to a given research question based on the research objectives to be achieved. The procedures in this study include data collection, data analysis, and conclusion drawing (Kosztyán et al., 2021). The literature search was conducted across four major academic databases: Google Scholar, ScienceDirect, Springer, and Taylor & Francis. The keywords used in data collection were acceleration or fast-track, the legal basis of acceleration, implementation of acceleration in education, social development, psychological development, and basic education. All data collected are primary data published in the form of national and international journals registered and indexed in Scopus, Springer, Taylor & Francis, with a publication limit of the last 10 years, namely 2014-2024. After the data was collected, the next step was to sort the collected articles based on the inclusion criteria that would be used in this literature study. The analytical framework applied to synthesise findings across the selected articles was a thematic-categorical approach, in which the socio-psychological impacts of fast-track policies were organised into three dimensions: (1) positive impacts, (2) neutral effects, and (3) negative consequences. This framework enabled a structured and comparative analysis of findings across diverse study contexts and methodologies.

The inclusion criteria used in this study are (1) studies that evaluate acceleration policies, (2) studies that analyse basic acceleration policies from 2014 to 2024, and (3) studies that focus on primary and junior secondary school education levels. Articles that did not meet the inclusion criteria were eliminated from the analysis process. The

authors collected articles sourced from Google Scholar, ScienceDirect, Springer, Taylor & Francis, which were then subjected to an article selection process. The article selection process was carried out in stages: identification, screening, and inclusion.

At the identification stage, 477 articles on accelerated education were found. Then, after screening, 97 articles were found that discussed acceleration in the field of basic education. Of the 97 articles, 30 were suitable for analysing the socio-psychological impact of acceleration policies in primary education

RESULTS

The phase of result presentation and elaboration is structured in line with the research objectives that the author aims to achieve. These objectives are: (1) examining the concept of fast track (acceleration); (2) examining the juridical and policy basis of fast track (acceleration) in basic education; (3) examining the policy of fast track (acceleration) implementation in basic education; and (4) evaluating the social and psychological development of students in fast track (acceleration) programmes at the basic education level. The data for the study were gathered based on the process of selecting articles used in phases: identification, screening, and inclusion. During the identification phase, 477 articles of accelerated education policy were identified through Google Scholar with a search engine to apply, publish, or perish.

The search terms used were accelerated education, accelerated education policy, basic education, socio-psychological effect, and educational psychology. The second step is screening of articles by reading each article by title, abstract, and keywords to determine if the article is related to the research subject, i.e., fast-track or acceleration policies in basic education, socio-psychological effect studies, and those studies from the last 10 years. In this screening process, 97 articles were gathered from 477 articles that were suitable for the research subject. In the last phase (including), 30 articles were found to be suitable for analysis of the socio-psychological impact on students of acceleration policy in primary school.

The articles were filtered for completeness of text in a bid to meet relevance and quality. All studies were searched for methodological quality, theory base, and contribution to knowledge on the socio-psychological impact of fast-track policies. Articles that gave empirical data, theoretical insights, or broad review articles were included in the final literature review.

The Concept of Fast Track (Accelerated) Education

The term "fast track" or "acceleration" is employed with different meanings. According to content analysis of articles gathered by researchers, acceleration is a policy that enables students to progress with the curriculum in less time and complete their education earlier (Steenbergen-Hu & Moon, 2011). Acceleration also refers to a study practice under which gifted students are permitted to progress faster

(McClarty, 2015; Plucker & Callahan, 2014; Tuhurima, 2016). The objective of the policy of acceleration is to provide high-level treatment in terms of accelerated learning for highly gifted students so that they can finish their course of studies in a shorter period than their other fellows under the mainstream programme. Hence, the acceleration programme or policy is an approach to meet the academic needs of highly able and talented students (Andayani, 2010; Buddeberg & Hornberg, 2017; Dare & Nowicki, 2019). Accelerated students may choose to skip one grade or move through a subject or topic at a faster rate than other students (Southern & Jones, 2004).

The concept of fast-track education is a pedagogical strategy used to cater to students with higher mental ability by enabling them to complete the curriculum within a shorter period than the normal track. Acceleration programmes take numerous forms, such as grade skipping, subject acceleration, dual enrollment, and early entrance, and are all designed to allow gifted students to learn at a faster rate with more sophisticated content (Assouline et al., 2015; Southern & Jones, 2004). Steenbergen-Hu and Moon (2011) believe that acceleration is one of the most scientifically supported and effective interventions utilised to increase the academic accomplishments of talented students, without causing negative effects in their social and emotional lives. Acceleration is not only a matter of instructional effectiveness; it is also a manifestation of equitable instructional differentiation, in which students are offered access to learning experiences aligned with their cognitive readiness (Dare & Nowicki, 2019; Plucker & Callahan, 2014).

Research by McClarty (2015) and Buddeberg and Hornberg (2017) indicate that acceleration can alleviate underachievement and disengagement in learning, which is commonly experienced by high-ability students in regular classroom settings. Additionally, acceleration fosters self-confidence and achievement orientation among students because they feel challenged and are able to explore their topics of interest at a deeper level. However, the achievement of acceleration programmes largely depends on the educational system's readiness, e.g., far-reaching mechanisms of gifted learner identification, teacher and parental support, and curriculum flexibility (Gross et al., 2003; Worrell et al., 2019). Acceleration has been integrated into education policy at the national level in most countries as a form of special educational service, for example, in Indonesia by Ministerial Regulation No. 70 of 2009, although its implementation remains not homogeneous (Tuhurima, 2016).

Thus, the concept of fast-track education is an adaptive, potential-centred, and evidence-based approach to instruction and learning. Its application is not necessarily about accelerating educational progress, but more about ensuring that students' preparedness to learn is matched with complexity in instruction. Thus, acceleration programmes need careful governance and overall systemic support to adequately foster the academic potential of gifted students

without truncating their social and affective development.

The Juridical Basis of Fast Track (Acceleration) Policy in Primary Education

The legal foundation for the implementation of the fast-track (acceleration) policy in the primary education sector in Indonesia is rooted in a number of regulations that emphasise the necessity to fulfill each child's right to develop optimally according to their potential and needs. Article 28H, verse (2) of the 1945 Constitution of the Republic of Indonesia states that everyone has the right to receive special facilities and treatment to obtain equal opportunity and benefit to achieve equality and justice. This article is the constitutional basis for the implementation of inclusive and adaptive education responsive to the needs of students with intellectual potential and/or exceptional talent.

The legal basis for implementing the fast-track programme in Indonesia is UUD 1945 Article 28H (2), UU No. 23/2002 on Child Protection Article 52, UU No. 20/2003 on the National Education System Articles 3 and 5, Permendiknas No. 34/2006 on the Development of Learners with Special Intelligence Potential and/or Talent, Permendiknas No.70/2009 on Inclusive Education for Learners with Disabilities and Potential for Special Intelligence and/or Talent Article 5, and PP No. 66/2010 on the Amendment to Government Regulation No. 17/2010 on Education Management and Implementation Article 53. These regulations emphasise the importance of providing children with special needs the opportunity to develop their talents and abilities (Fachrudin, 2019).

Implementation of Fast Track (Acceleration) Policy in Primary Education

The school has a specific process through which they implement the acceleration policy. They, first and foremost, get approval from the department of education and culture. That approval is their legal basis on which they implement the acceleration programme (Tuhurima, 2016). There are some factors that need to be taken into consideration when having accelerated policies or programmes. They involve hiring students with high IQ, above 130, designing specially customised curriculum to be imparted to accelerated classes, providing necessary infrastructure and facilities, and appointing appropriately qualified and seasoned instructors (Zarkasyi, 2016). Policy acceleration implementation might be greater than one manner, such as missing grades or advancing into classes earlier than expected (McClarty, 2015). One of the mechanisms through which academic acceleration is done is curriculum compaction, with subject and value-based options (Dare & Nowicki, 2019). The effectiveness of the accelerated options is dependent on the cognitive ability and learning potential of the students. Accelerated programmes are implemented on a fixed education calendar. The policy of acceleration is enforced at the primary school level in grade four. Throughout this roll-out, content covered at grades 4, 5, and

6 is completed in two years (Cindy Alfianita & Gunansyah, 2018). Content selection is done considering the difficulty level and weightage given to it. Collaborative learning methodologies are also applied. Teachers' responsibilities in this regard are crucial because they need to be fully cognizant of the students' traits, particularly their mental acuity.

The implementation of acceleration (fast-track) policies at the primary school level must be planned in a systematic manner and implemented on a regulation-based system. The formal process begins with the application for approval from the local education authority, which legally has the right to approve the implementation of acceleration programmes in schools (Tuhurima, 2016). The success of these programmes is determined by a series of key factors, including the selection of the gifted students with an IQ of 130 or higher, the establishment of an adapted and specialised curriculum, the availability of supporting facilities, and the professional competence of the teaching staff entrusted with their educational process (Zarkasyi, 2016). Acceleration may be attained by various means, such as grade skipping, early entry, or curriculum compaction—a method of compacting learning material on the basis of competence acquisition and students' needs (Dare & Nowicki, 2019; Southern & Jones, 2004). Curriculum compaction allows learners to bypass what they have already learned, hence streamlining the learning process to become more meaningful and efficient.

A study by McClarty (2015) indicates that acceleration not only requires mental readiness but also places a demand on students to have adaptive and flexible learning skills to cope with a fast-paced instructional pace. Acceleration policies in primary education are typically applied at grade four, where students progress through the learning of grades four, five, and six within two years. Selection of learning materials applied in this curriculum is dependent on the relative importance and complexity of each competency standard (Cindy Alfianita & Gunansyah, 2018). Collaborative learning strategies to further academically and to facilitate students' social-emotional life are also employed. Roles in implementation are significantly driven by the teacher, particularly in selecting students' intellectual traits, managing classroom dynamics, and developing responsive learning interventions (Assouline et al., 2015).

Though acceleration policies hold enormous promise for optimising the academic achievement of gifted students, their implementation requires serious institutional and pedagogical preparedness. Without explicit selection procedures, effective teacher training, and sound assessment policies, acceleration can lead to new inequities in the elementary school system (Colangelo et al., 2004; Worrell et al., 2019). Therefore, application of acceleration policies must be selectively and data-driven in order to not only enable educational advancement but also ensure students' social and psychological development.

Socio-Psychological Impact of Fast-track (acceleration) Policies for Students in Primary Education

Positive Socio-Psychological Impacts

Based on the analysis of the articles collected by the researchers, the fast track or acceleration programme policy has a positive impact on the self-esteem and motivation of students. Gifted students usually feel a sense of accomplishment and satisfaction with being appropriately challenged in their studies (Hemelt & Lenard, 2020). Yet, this feeling of achievement is often matched with enhanced stress and anxiety because of heightening academic pressures (Reis & Renzulli, 2019). The research implies that though acceleration will be able to enhance self-confidence, it is also likely to exert excessive pressure upon pupils, necessitating sufficient support systems in order to alleviate stress. These findings are consistent with self-concept theory, which posits that a student's perception of their own capabilities fundamentally shapes their academic motivation and emotional regulation (Ranny et al., 2017; Syahraeni, 2020).

The results showed that there were no considerable negative effects of the policy of the acceleration programme and even had beneficial results for gifted students (Siegle et al., 2013). The findings of the study demonstrated that students who were involved in the acceleration programme did not experience negative effects on social and psychological existence, especially of students' emotions. Another result of the study found that the students were as or even higher in social acceptance and extracurricular activities than non-accelerated students. The results of the study are evidenced by studies (Plucker & Callahan, 2014) which support the findings that the acceleration programme policy is positively effective on students. The study uncovered that acceleration has the potential to benefit students educationally and boost social and emotional well-being. The emotional maturity of the students dictates the students' social adjustment (Susilowati, 2013).

Based on the findings, the implementation of acceleration policies for gifted students is confirmed to have positive effects on socio-emotional growth of children, including self-concept, self-esteem, study attitude, motivation, self-confidence, and career aspiration (Kim, 2016). The positive effect is referring to learners' self-concept of their own capabilities, values, and self-identity. The mentioned above self-concept is a perception of himself which will further determine his behavior (Ranny et al., 2017; Syahraeni, 2020). Having this self-concept will affect students in thinking, feeling, perceiving, and acting. Knowing the self-concept of the students, then these students may or most likely will have some sense of self-esteem or value. If this sense of self-worth is enhanced and already owned by students, students will have an academic attitude, be motivated to always excel, and be more confident in themselves and their environment, which eventually affects students' careers in the future. These positive outcomes are well-grounded in social-

emotional learning (SEL) frameworks, which emphasise the role of self-awareness and emotional competence in academic achievement and life success (Steenbergen-Hu & Moon, 2011; Worrell et al., 2019).

Neutral Effects on Social Development

Research findings by Wai (2015) suggest that the policy of acceleration programmes does not impact social development much or is indifferent. This suggests that it has neither a positive nor a negative impact on the social development of students, specifically on the ability to form friendships. The same conclusions are obtained from studies by Rogers (2015) that state acceleration policy provides low to moderate social-emotional benefits to students. This means that the acceleration policy has not had a high positive impact on the social-emotional development of students. From a theoretical standpoint, this neutral pattern may be explained by the fact that acceleration programmes are primarily designed to address cognitive and academic needs, with insufficient attention to the social-emotional dimensions of gifted learners' development (Worrell et al., 2019). When the educational environment does not provide structured opportunities for peer social interaction, the socio-emotional effects of acceleration tend to be limited or negligible.

Negative Socio-Psychological Impacts

Contrary to the positive findings described above, Nafsiyah (2021) reported several negative impacts associated with the implementation of acceleration policies in schools. The adverse consequence is that the students cannot cope with their peers or have problems in social integration due to less activity time with peers and due to age gaps with their peers. Students feel isolated and find it difficult to make friends. This is because students are required to do well academically, leaving little time for social interaction and the natural development of peer relationships. Furthermore, according to the findings of the study, it was discovered that students missed out on leadership skill development because accelerated students had a tendency of feeling rejected by their older counterparts. These negative outcomes can be interpreted through the lens of social adjustment theory: when accelerated students are placed with older peers but have not yet reached the same level of social maturity, the resulting mismatch in social dynamics can create barriers to belonging and hinder the development of interpersonal competencies (Andayani, 2010; Kulik & Kulik, 2004). This underscores the critical importance of ensuring that academic acceleration is accompanied by robust social-emotional support structures, including counseling services, peer mentoring programmes, and inclusive extracurricular activities that bridge age-related social gaps.

DISCUSSION

Acceleration is a policy aimed at providing outstanding treatment in the guise of accelerated learning to students possessing outstanding abilities, such that such students can complete their education before the normal (regular programme). Based on the

analysis of the article, it can be argued that the application of the acceleration policy has positive, neutral, and negative impacts on social and psychological development, especially on students' emotions. Socio-emotional factors affecting children, like self-concept, self-esteem, learning attitude, motivation, confidence, and vocational desires, all have positive impacts. Academic benefits as well as social and emotional adaptation are also impacted by acceleration policies that can leave students. However, results show that there is no effect on social growth using acceleration programmes or that they have the same effect as having no effect. This implies that it neither contributes nor inhibits students' social development, specifically the formation of friendships. Alternatively, there are findings to the effect that the adverse effect of the adoption of the acceleration policy is that the students do not easily mix with their agemates due to the lower amount of activity time with peers and the age difference. This is because students should perform well in academics. Moreover, students are deprived of the opportunity to become leaders since fast children are ostracised by their peers who are older than them.

The findings of this study carry several specific and actionable implications for key stakeholders involved in the implementation of fast-track programmes at the primary education level. For policymakers, it is recommended that acceleration programme regulations be revised to include mandatory provisions for socio-emotional support services alongside academic acceleration, ensuring that the holistic development of gifted students is embedded within the legal and institutional framework of fast-track education. For school administrators, this study recommends implementing regular monitoring mechanisms to assess the social and emotional well-being of accelerated students, including ensuring structured opportunities for peer interaction, extracurricular participation, and integration with age-appropriate social activities so that accelerated students do not become socially isolated. For teachers, the findings highlight the need for targeted professional development training that equips educators to identify early signs of social isolation, emotional stress, or peer rejection among gifted students, and to apply differentiated socio-emotional interventions in response. Future research should consider longitudinal studies to track the long-term socio-psychological outcomes of acceleration programme participants, as well as comparative studies across different national and cultural contexts to better understand the contextual factors that moderate the effects of fast-track policies on students' social and emotional development.

CONCLUSION

This systematic review demonstrates that fast-track (acceleration) policies in primary education exert a complex, multidimensional influence on students' social and psychological development. Synthesising the selected studies revealed three broad patterns of impact. Positively, acceleration can strengthen gifted students'

self-concept, self-esteem, learning attitude, motivation, self-confidence, and career aspirations, while providing the academic challenge needed to reduce boredom and underachievement. In several contexts, the effect on social development is neutral, neither advancing nor hindering students' ability to form friendships, largely because acceleration programmes are designed around cognitive rather than social-emotional needs. Negatively, inadequately supported acceleration may leave students socially isolated, reduce the time available for peer interaction, and limit the development of leadership and interpersonal skills because of age gaps with older classmates. Taken together, the evidence indicates that the academic benefits of acceleration can be sustained only when they are accompanied by deliberate socio-emotional support. Fast-track policy at the basic education level should therefore be implemented selectively, holistically, and on the basis of sound evidence, pairing accelerated learning with counselling, peer mentoring, and inclusive social opportunities so that gifted students can develop as whole individuals.

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From Learning to Assessment: Development and Validation of a REACT-Based Digital Numeracy Literacy Instrument

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ABSTRACT

This study aimed to develop and validate a REACT (Relating, Experiencing, Applying, Cooperating, and Transferring)-based numeracy literacy assessment instrument for Indonesian elementary school students. The study employed the Four-D (Define, Design, Develop, and Disseminate) development model. During the development stage, the instrument was evaluated by five expert validators specialising in mathematics education and educational linguistics. A pilot study involving 30 elementary school students was conducted to assess item clarity and preliminary psychometric quality, followed by a field test with 120 students to examine the instrument's validity, reliability, discrimination power, and difficulty level. Content validity analysis showed high validity, with Aiken's V values ranging from 0.85 to 0.88 overall. The field testing demonstrated that most items satisfied acceptable psychometric criteria and effectively differentiated students across varying levels of numeracy competence. Unlike conventional numeracy assessments that primarily emphasise procedural competence, the proposed instrument operationalises contextual problem solving through the REACT framework by integrating experiential learning, collaborative reasoning, and knowledge transfer into the assessment process. Consequently, the

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instrument offers a valid and practical diagnostic tool for assessing contextual numeracy literacy while extending current educational assessment practices toward more authentic competency-based evaluation in elementary education.

Keywords: Development, instrument, literacy and numeracy, REACT learning strategy

INTRODUCTION

Early numeracy literacy has become one of the most essential competencies in contemporary education because it provides the cognitive foundation for mathematical reasoning, problem-solving, and informed decision-making throughout life (Bailey & Bulotsky-Shearer 2022; Blunch 2014; Mtika & Abbott 2023). Beyond mastering arithmetic procedures, numeracy literacy enables learners to interpret quantitative information, evaluate evidence, and apply mathematical reasoning across authentic contexts encountered in education, society, health, and everyday life (Carpenter et al., 2017; Jayaraman et al., 2018). Consequently, developing numeracy competence from the early years of schooling has become a strategic priority in many educational systems (Carpenter et al., 2017; McNaughton et al., 2011; Nandyala et al., 2018). Empirical studies consistently demonstrate that children who acquire strong numeracy competencies during primary education achieve higher academic performance in subsequent educational stages and exhibit greater confidence in solving unfamiliar problems (Fauzan et al., 2024; Rohmah et al., 2022). Likewise, the successful development of numeracy literacy is strongly influenced by the interaction between school learning experiences and family support. Previous studies have shown that parental expectations, home numeracy activities, and early mathematical interactions substantially contribute to children's mathematical achievement and long-term learning trajectories (Bonifacci et al., 2022; Lestari et al., 2022; Martini & Sénéchal, 2012). These findings collectively suggest that numeracy literacy should not be viewed merely as a curriculum outcome but as a multidimensional competence that develops through continuous interaction between learners, instructional practices, and authentic learning environments.

Despite its recognised importance, improving numeracy literacy remains a significant challenge in elementary education. Numerous instructional innovations, including project-based learning, ethnomathematics, realistic mathematics education, digital learning applications, and interactive mathematical comics, have demonstrated positive effects on students' mathematical understanding and engagement (Aini et al., 2024; Fauzan et al., 2024; Kustantina et al., 2022; Utama et al., 2023). These approaches emphasise contextual learning by connecting mathematical concepts with students' daily experiences, thereby promoting deeper conceptual understanding rather than procedural memorisation. Nevertheless,

evidence indicates that many elementary students continue to experience considerable difficulties when confronted with contextual mathematical problems requiring reasoning, interpretation, and flexible application of mathematical knowledge (Situmorang & Sinaga, 2022; Zulfayani et al., 2023). The decline in students' numeracy performance following the COVID-19 pandemic further illustrates the vulnerability of existing instructional and assessment practices in supporting sustainable numeracy development (Fatonah et al., 2023; Marthyane Pratiwi et al., 2024). These persistent challenges suggest that improving instructional approaches alone may be insufficient if assessment practices remain unable to capture the broader competencies required for meaningful numeracy literacy.

The growing emphasis on contextual learning has also transformed expectations regarding educational assessment. Contemporary assessment is no longer expected merely to determine whether students obtain correct answers but also to provide evidence of how learners construct, apply, and transfer mathematical knowledge across different situations (Hijriani et al., 2022). International assessment frameworks, particularly the Programme for International Student Assessment (PISA), have substantially shifted the measurement of numeracy from procedural calculation toward the application of mathematics in authentic real-world contexts. Similarly, Indonesia's Minimum Competency Assessment (AKM) was introduced to encourage schools to assess higher-order reasoning rather than routine computational skills (Hidayah et al., 2021b; Humairah et al., 2024). These developments represent important advances in educational assessment because they recognise that mathematical competence extends beyond mastery of algorithms. However, both frameworks primarily conceptualise numeracy as an individual's cognitive achievement demonstrated through responses to standardised contextual tasks. While contextual scenarios are incorporated into the assessment items, the assessment process itself remains predominantly outcome-oriented, focusing on the accuracy of individual performance rather than on the learning dimensions through which mathematical understanding is constructed and subsequently transferred to unfamiliar situations.

Consequently, although AKM and PISA have significantly contributed to advancing contextual numeracy assessment, several conceptual limitations remain when these frameworks are considered from the perspective of experiential learning. Existing numeracy assessments generally emphasise contextual problem solving as the final manifestation of competence but provide limited opportunities to examine how learners relate prior knowledge to new mathematical concepts, construct understanding through direct experience, collaborate with peers during mathematical reasoning, and transfer acquired knowledge to novel situations (Rohendi, 2019; Via & Abadi 2021). These learning processes constitute essential characteristics of

authentic mathematical competence, yet they are rarely operationalised as measurable constructs within conventional assessment instruments. As a result, students may demonstrate correct procedural or contextual solutions without necessarily exhibiting the experiential, collaborative, and transferable competencies required for meaningful mathematical literacy. This limitation becomes particularly relevant in elementary education, where mathematical understanding is actively constructed through interaction, exploration, and guided social learning rather than through individual performance alone.

The limitations of conventional assessment become increasingly evident when viewed alongside current theories of learning. Traditional paper-based assessments generally evaluate the products of learning after instruction has occurred, assuming that contextual performance adequately represents students' underlying mathematical competence. However, learning theories increasingly emphasise that meaningful understanding develops through active engagement with authentic experiences, collaborative inquiry, and repeated opportunities to apply knowledge across multiple contexts. Consequently, assessment instruments that focus exclusively on individual cognitive outcomes may underestimate important dimensions of mathematical competence developed during the learning process itself. This conceptual mismatch highlights the need for assessment approaches capable of capturing not only whether students can solve contextual problems but also whether they are able to connect prior knowledge with new situations, learn through experience, collaborate in constructing mathematical understanding, and transfer acquired knowledge to unfamiliar contexts. Addressing these dimensions requires assessment frameworks that move beyond traditional measurement paradigms toward more authentic representations of contextual numeracy competence.

This study does not simply develop another numeracy instrument; rather, it reconceptualises contextual numeracy assessment by embedding the REACT dimensions as measurable assessment constructs, thereby extending existing assessment frameworks beyond procedural and contextual mathematical performance toward experiential, collaborative, and transferable competencies. The study fills this gap by creating and testing a REACT-based numeracy literacy tool that is appropriate for Indonesian elementary school students. More and more people are talking about using REACT (Relating, Experiencing, Applying, Cooperating, and Transferring) to facilitate people learning how to read and write numbers. This model focuses on active learning and getting students involved, which facilitates them connecting math ideas to real-life situations and deepen their understanding and use of math skills. The REACT framework has been shown to facilitate people understanding math concepts and how to use them better, which is necessary for developing numeracy literacy (Faqih et al., 2022; Utama et al.,

2023). Internationally, frameworks such as the OECD PISA numeracy assessment emphasise the application of mathematics in real-world contexts, aligning with the 'Applying' and 'Transferring' dimensions of REACT. Furthermore, instrument validation draws from established psychometric principles, which inform our approach to content validity and reliability testing.

LITERATURE REVIEW

Traditional static assessments often impose high extraneous cognitive load, failing to measure students' true capabilities (Sweller, 2022). In contrast, contextual strategies like REACT align with generative learning principles, which have been proven to foster deeper understanding by actively engaging students in meaning-making processes rather than rote memorisation (Fiorella, 2023). Unlike traditional numeracy tests that often emphasise procedural fluency, the present instrument is explicitly designed around the REACT framework, which integrates real-world contextualisation, collaborative problem-solving, and knowledge transfer into the assessment structure. This distinguishes it from existing tools such as the Indonesian National Assessment (AKM), which, while measuring literacy and numeracy, does not systematically embed experiential and cooperative learning phases within the test items themselves.

The need for more authentic assessment has encouraged educational researchers to reconsider the relationship between learning theory and assessment design. Rather than functioning solely as instruments for measuring learning outcomes, contemporary assessments are increasingly expected to represent the cognitive and social processes through which knowledge is constructed. This perspective is consistent with Cognitive Load Theory, which argues that effective learning occurs when instructional and assessment activities minimise unnecessary cognitive demands while directing learners' cognitive resources toward meaningful schema construction (Sweller, 2022). Likewise, Generative Learning Theory emphasises that deep understanding develops when learners actively organise, integrate, and apply new information instead of merely recalling previously memorised knowledge (Fiorella, 2023). These perspectives suggest that assessment should move beyond verifying whether students can produce correct answers and instead capture the cognitive processes involved in constructing, applying, and transferring mathematical knowledge. Consequently, assessment instruments should be conceptually aligned with learning theories that emphasise active knowledge construction rather than passive knowledge reproduction.

Among contextual learning approaches, the REACT framework—consisting in Relating, Experiencing, Applying, Cooperating, and Transferring—offers a particularly relevant conceptual foundation for integrating learning and assessment. Existing studies have consistently demonstrated that REACT improves students' conceptual understanding, mathematical reasoning, motivation, and

engagement because mathematical ideas are introduced through meaningful experiences before being applied to authentic situations (Faqih et al., 2022; Utama et al., 2023). Each REACT dimension represents a distinct learning process. Relating encourages learners to connect new mathematical concepts with prior knowledge and familiar situations; Experiencing emphasises exploration through authentic activities; Applying requires learners to utilise mathematical concepts to solve contextual problems; Cooperating promotes collaborative reasoning and shared problem solving; and Transferring challenges students to extend acquired knowledge to unfamiliar situations. Collectively, these dimensions reflect how mathematical competence develops progressively through experience, interaction, application, and adaptation rather than through isolated procedural performance.

Despite its demonstrated effectiveness as an instructional strategy, previous studies have almost exclusively positioned REACT as a pedagogical approach for improving mathematics learning outcomes. Research has primarily examined its influence on students' achievement, motivation, classroom engagement, and conceptual understanding, while considerably less attention has been devoted to how REACT may inform the design of educational assessment instruments. Consequently, the potential of REACT to serve as a conceptual framework for assessment remains largely underexplored. This distinction is theoretically important because instructional models and assessment frameworks pursue different objectives. Instructional models describe how learning should occur, whereas assessment frameworks define which competencies should be represented, operationalised, and measured. Transforming REACT from an instructional strategy into an assessment framework therefore requires translating each learning dimension into observable assessment constructs capable of producing valid and reliable evidence regarding students' contextual numeracy competence.

This study argues that the contribution of REACT extends beyond supporting instruction by providing a multidimensional conceptual structure for numeracy assessment. Conventional numeracy instruments generally evaluate students' ability to interpret information, perform mathematical procedures, and solve contextual problems through individual responses. Although these competencies are fundamental, they provide only a partial representation of mathematical literacy because they primarily assess the outcomes of learning rather than the processes through which mathematical understanding is constructed. In contrast, a REACT-based assessment conceptualises contextual numeracy as an integrated construct encompassing students' ability to connect prior knowledge with new situations (Relating), develop understanding through authentic experiences (Experiencing), apply mathematical reasoning to meaningful contexts (Applying), construct solutions collaboratively (Cooperating), and transfer

acquired knowledge across unfamiliar situations (Transferring). Consequently, the dimensions represented within the assessment are broadened from procedural and contextual performance toward experiential, collaborative, and transferable mathematical competence.

This reconceptualisation also has important implications for contextual problem-solving assessment. Existing assessments such as AKM and PISA primarily infer students' reasoning ability from their responses to contextual tasks, whereas the present framework intentionally embeds the learning dimensions that support successful contextual reasoning into the design of the assessment itself. Rather than treating context merely as a background for mathematical problems, the proposed instrument operationalises context as a multidimensional learning environment in which students activate prior experiences, construct mathematical meaning, collaborate when appropriate, apply concepts, and demonstrate transfer of knowledge. Consequently, contextual numeracy is assessed not only as the ability to obtain correct answers in realistic situations but also as the capacity to employ mathematical knowledge through authentic cognitive and social processes. This perspective extends existing approaches to contextual assessment by integrating learning-oriented competencies directly into the measurement framework.

Accordingly, the theoretical contribution of this study lies in extending the conceptual foundation of contextual numeracy assessment. Instead of viewing assessment solely as a mechanism for evaluating mathematical performance, the proposed instrument positions assessment as a representation of how mathematical competence develops through experience, collaboration, contextual application, and knowledge transfer. In doing so, this study bridges learning theory and educational measurement by operationalising the REACT dimensions as measurable assessment constructs rather than treating them exclusively as instructional principles. This conceptual extension contributes to educational assessment by offering an alternative framework for developing numeracy instruments capable of capturing broader dimensions of authentic mathematical competence that have received limited attention in conventional assessment models.

Although previous studies have demonstrated the effectiveness of contextual learning approaches in improving students' mathematical achievement, most investigations have concentrated on evaluating learning outcomes rather than examining how contextual learning principles can inform the design of educational assessment instruments. Studies involving project-based learning, ethnomathematics, interactive mathematics media, and REACT have consistently reported improvements in students' numeracy performance, conceptual understanding, and learning motivation (Aini et al., 2024; Fauzan et al., 2024; Kustantina et al., 2022; Muliani et al., 2022; Utama et al., 2023). However, these

studies generally position assessment as a means of documenting instructional effectiveness rather than as an integral component of the learning framework itself. Consequently, the assessment instruments employed in previous research largely continue to measure conventional cognitive outcomes, providing limited evidence regarding how students relate prior knowledge to new mathematical concepts, develop understanding through authentic experiences, collaborate in mathematical reasoning, and transfer acquired knowledge across unfamiliar situations. This indicates that the conceptual relationship between contextual learning theory and educational assessment remains insufficiently developed within the current literature.

A second gap concerns the operationalisation of contextual numeracy assessment. Existing assessment frameworks, including nationally implemented assessments such as AKM and internationally recognised assessments such as PISA, have substantially advanced the measurement of contextual mathematical reasoning by emphasising authentic problem-solving situations. Nevertheless, contextualisation within these assessments is primarily represented through realistic problem contexts rather than through multidimensional learning processes. In other words, students' mathematical competence is inferred from their responses to contextual tasks, while the experiential, collaborative, and transferable dimensions through which contextual understanding develops remain largely outside the scope of measurement. Consequently, current assessment practices provide valuable evidence regarding students' mathematical performance but comparatively limited information regarding broader competencies that characterise authentic numeracy learning. This unresolved issue becomes particularly important in elementary education, where mathematical understanding develops through continuous interaction among prior experience, exploration, collaboration, application, and knowledge transfer.

Building upon these limitations, the present study proposes that the REACT framework offers an opportunity to extend the conceptual foundation of contextual numeracy assessment. Rather than employing REACT solely as an instructional strategy, this study operationalises its five dimensions as measurable assessment constructs that guide the development of assessment items and scoring indicators. From this perspective, contextual numeracy is conceptualised not only as the ability to solve mathematical problems situated in realistic contexts but also as the capacity to connect prior experiences with new concepts, construct understanding through authentic engagement, collaborate in mathematical reasoning, apply concepts meaningfully, and transfer knowledge across different situations. This reconceptualisation shifts the role of assessment from merely documenting learning outcomes toward representing the multidimensional competencies involved in meaningful mathematical learning.

Accordingly, the theoretical contribution of this study extends beyond

the development of a psychometrically valid assessment instrument. Conceptually, this research contributes to the field of educational assessment by integrating learning-oriented competencies into the measurement of contextual numeracy. Whereas conventional numeracy assessments predominantly emphasise procedural fluency, mathematical reasoning, and contextual problem solving, the proposed framework broadens the construct of numeracy assessment by explicitly incorporating experiential engagement, collaborative reasoning, and knowledge transfer as measurable dimensions of competence. By operationalising these dimensions within the assessment design, the study establishes a closer alignment between contemporary learning theories and educational measurement, thereby extending existing perspectives on authentic numeracy assessment. Consequently, the contribution of this study lies not only in producing a reliable assessment instrument but also in proposing an alternative conceptual model for assessing contextual numeracy in elementary education.

The novelty of this study therefore resides in two complementary aspects. First, unlike previous studies that primarily investigated REACT as a pedagogical strategy to improve mathematics instruction, this study reconceptualises REACT as a framework for educational assessment by translating its five learning dimensions into measurable assessment constructs. Second, while existing numeracy instruments generally evaluate contextual mathematical performance through individual cognitive responses, the proposed instrument embeds experiential learning, collaborative reasoning, authentic application, and knowledge transfer within the assessment structure itself. Consequently, the instrument extends existing approaches to contextual numeracy assessment by providing a more comprehensive representation of mathematical competence that reflects both cognitive performance and learning-oriented processes. This dual contribution differentiates the present study from previous instrument-development research and positions it within the broader discourse on authentic educational assessment.

Based on these considerations, this study aims to develop and validate a REACT-based numeracy literacy assessment instrument for elementary school students in Indonesia using the Four-D development model. Specifically, the study seeks to examine the content validity, construct quality, and psychometric properties of the proposed instrument while evaluating its capacity to represent the multidimensional competencies embedded within the REACT framework. Through this approach, the study is expected to provide both a practically applicable assessment instrument for elementary mathematics education and a conceptual contribution to the continuing development of contextualised educational assessment.

METHODOLOGY

The 4D development method is used in this study. It has four steps: define, design,

develop, and disseminate. In the first step, we looked at the needs and problems that elementary school students have with their math and reading skills. The first step was to look over the curriculum and other relevant materials to get a sense of what numeracy and literacy skills needed to be learned. At this point, the students' traits were also looked at so that the development of the instrument could be based on what they knew and needed. To make sure the instrument was useful and made sense, they also looked at math topics that people use in their daily lives.

The next step is design, where the instrument's design starts based on the needs analysis that was done in the define stage. The REACT (Relating, Experiencing, Applying, Cooperating, and Transferring) learning strategy is used to arrange the complex multiple-choice questions that make up this instrument according to the indicators of numeracy literacy. The design process includes making an instrument lattice that outlines the test's purpose, content, and structure. Each question is meant to measure students' ability to think critically and solve problems in real life. The instrument is made so that children in elementary school can easily and clearly understand and answer the questions. The development stage involved constructing a model of the tool and getting it approved by five math education specialists. Validators then looked at the prototype of the tool numerous times and got comments from experts to make it more accurate. Content validity was quantified using Aiken's V formula. A score of $V > 0.80$ was considered valid. A small pilot test was also done with 30 elementary school pupils to assess how clear the instrument was and make sure it could be utilised properly in a math class. The results of this pilot test were used to improve the tool so that it could be used by more people.

At the distribute stage, the modified tool was tested again on a larger number of 120 students to check if it was trustworthy and valid in real life. We utilised SPSS to analyse the results of this pilot test, look at factors like the validity of the content, the dependability of the results, the ability to tell the difference, and the difficulty of the questions. With this analysis, each thing on the instrument is better so that it provides consistent and reliable measurement results. There is a lot of information available for each step of the 4D development technique. This means that other scientists can do the same things and get the same findings. We had professionals check it out and did field tests to make sure that the instrument can be used properly in different types of schools. The REACT-based numeracy literacy tool that was produced as part of this study should be a good and effective technique to test primary school pupils' arithmetic skills in line with national education requirements. Each stage in the 4D development method is represented in more detail in Figure 1.

Sample Size Justification

The sample sizes employed in this study were determined based on methodological recommendations for educational instrument

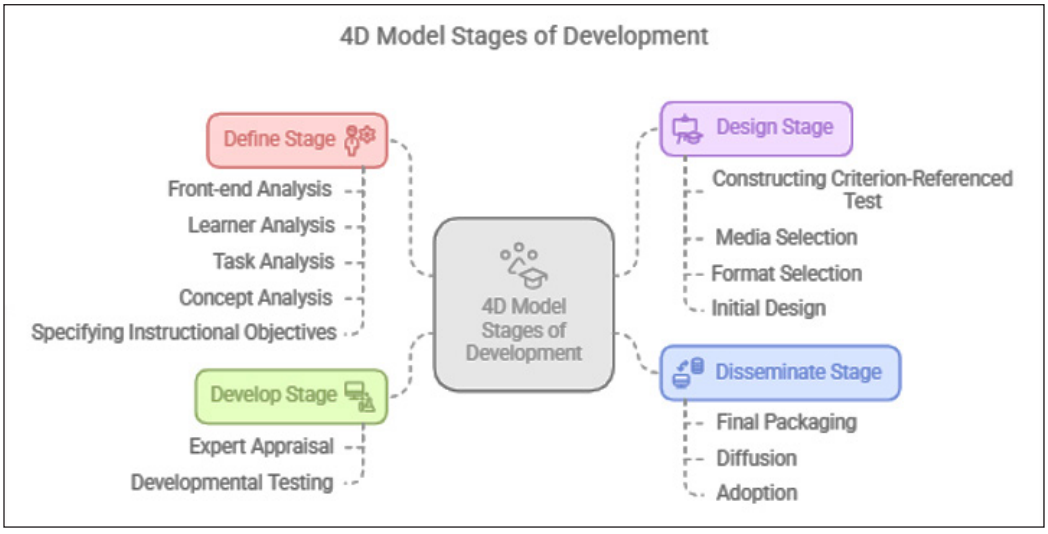

Figure 1. 4D model stages of development

development rather than statistical hypothesis testing. During the content validation stage, the instrument was evaluated by five expert validators consisting of specialists in mathematics education, educational assessment, and language. This number is considered adequate for content validity evaluation using Aiken's V because a panel of between five and ten experts is generally regarded as sufficient to provide stable and reliable judgments regarding item relevance, clarity, and representativeness (Aiken, 1985; Lynn, 1986).

A pilot study involving 30 elementary school students was subsequently conducted to examine the clarity, readability, comprehensibility, and preliminary functioning of the assessment of items. Pilot samples of approximately 20-30 participants are commonly recommended in instrument development studies to identify ambiguous wording, administration problems, and initial psychometric characteristics before large-scale implementation (Johanson & Brooks, 2010).

For the field-testing phase, the instrument was administered to 120 elementary school students. This sample size satisfies commonly accepted recommendations for preliminary psychometric evaluation, including item validity, internal consistency, discrimination index, and difficulty index analyses. Methodological literature on educational measurement indicates that samples exceeding 100 participants are generally considered adequate for item analysis and reliability estimation during the development of educational assessment instruments (DeVellis, 2017). Therefore, the selected sample sizes were considered methodologically appropriate for each phase of the Four-D development model because each stage served different objectives, namely expert judgment for content validation, pilot testing for instrument refinement, and field testing for psychometric evaluation.

Ethical Considerations

This study was conducted in accordance with ethical principles governing educational research involving children. Prior to data collection, permission to conduct the study was obtained from the participating elementary school and the relevant educational authorities. Parents or legal guardians of all participating students were informed about the objectives, procedures, and voluntary nature of the study, and informed consent was obtained before students participated in the research. In addition, verbal assent was sought from the students to ensure that participation was based on their willingness and understanding. Participants were informed that they could withdraw from the study at any stage without academic consequences. To protect participants' privacy, all collected data was anonymised, treated confidentially, and used exclusively for research purposes. No personally identifiable information was included in the data analysis or publication of the findings.

RESULTS AND DISCUSSION

Define Stage

At the define stage in the development of REACT-based numeracy literacy instruments for primary school students, the first step is to analyse the needs and problems related to numeracy literacy. Based on the literature review and curriculum study, it was found that numeracy literacy is one of the essential competencies for 21st century students, which involves not only numeracy skills, but also critical thinking, analytical and problem-solving skills in everyday contexts. Unfortunately, the results of international studies such as PISA show that Indonesian students' numeracy literacy is still below average, signaling an urgent need to improve this skill at the basic education level.

Furthermore, a curriculum analysis was conducted to understand the core competencies that need to be achieved in numeracy literacy according to national standards. The curriculum underlines the importance of contextualised numeracy skills, which involve the application of mathematics in real life. Based on this analysis, common daily mathematics topics, such as basic number operations, measurement and data representation, were selected as the main focus in developing the instrument to make it relevant to students' lives and to enhance their critical and analytical thinking skills. Analysing student characteristics is also an important part of this stage. By understanding that elementary school students are in the concrete cognitive stage of development, the instruments designed should be simple and contextual, using language that is easy to understand and situations that are close to students' daily experiences. This method should facilitate students understanding the questions better and feel more like they are part of the learning process.

The define stage also included looking at the research on effective learning models to facilitate people becoming better at math and reading. The REACT (Relating, Experiencing, Applying, Cooperating, and Transferring) strategy was chosen because

it lets students connect math ideas to real-life situations, work together with friends, and use what they know in new ways. People think that this strategy will make learning math and reading more interesting and useful for students. The define stage gives us a lot of information that we can use to make tools that fit the curriculum and the students' needs, and that also use new ways of teaching. It is hoped that this will facilitate making numeracy literacy tools that are useful, work well, and can fully measure what students can do.

Design Stage

During the design phase of making REACT-based numeracy literacy tools for elementary school students, a number of design steps are taken to create question grids and tools that meet the numeracy literacy indicators that were set during the defined phase. Initial display of REACT-Based Numeracy Literacy AKM Questions is shown in more detail in Figure 2. Making the instrument grid is the first step in the design process. The grid includes the goals, the skills that will be measured, the question of indicators, and the types of questions that will be used. Each question was based on one of the five parts of the REACT strategy: relating, experiencing, applying, cooperating, and transferring. This made sure that the test not only measured basic math skills but also critical thinking skills and the ability to use them in real life.

In this design process, the questions are made in the form of complex multiple choices that require students to analyse and interpret information before choosing an answer. Complex multiple choices were chosen because they are able to provide a higher challenge, so students need to think more deeply and be actively involved in the problem-solving process. Each question includes daily life contexts that are close to students' experiences, such as situations in families, schools, and neighborhoods, so that students feel more connected to the material being tested. To facilitate instrument testing and maintain consistency, the initial draft of the instrument was organised into several forms of questions with varying difficulty levels, which included questions with low, medium, and high difficulty levels. This variation aims to measure students' abilities comprehensively, from basic skills to more in-depth analytical abilities. The questions were then categorised by difficulty level so that the results of the instrument evaluation could cover a wide spectrum of student abilities.



Figure 2. Initial display of REACT-based numeracy literacy AKM questions

Also, the instructions for how to answer the questions are written in simple, clear language that is appropriate for elementary school students. Each clue is set up and visualised in Figure 3 so that students can easily understand what they need

to do, and each problem has pictures or real-life examples that facilitate students understand the problem's context, and each problem is accompanied by illustrations or real examples that support students' understanding of the context of the problem which is visualised in Figure 4. Students can better understand the problem and be more motivated to answer it when they can see it in pictures.

Students can better understand the problem and be more motivated to answer it when they can see it in pictures.

Students will get a notification on their app screen if they answer the question correctly or incorrectly, as shown in Figure 5.

The outcome of this design stage is a tool in the form of an initial prototype that has a range of numeracy and literacy questions that follow the REACT method and are organised according to the grids that have been made. We are ready to test this prototype again in the next step, with the goal of making a tool that is valid, reliable, and useful for measuring elementary school students' math and reading skills.

Stage of Development

At the development stage of the research on making REACT-based math and reading tools for elementary school students, the tools that were designed at the design stage are then made into prototypes and tested to make sure they work, are valid, and reliable. Prototyping, expert validation, and limited student testing are some of the important steps that happen at this stage. The first thing that needs to be done at this stage is to make instrument prototypes based on the grids and question designs that have been chosen.



Figure 3. Display of problem-solving instructions



Figure 4. Display of REACT-based numeracy literacy AKM questions and text

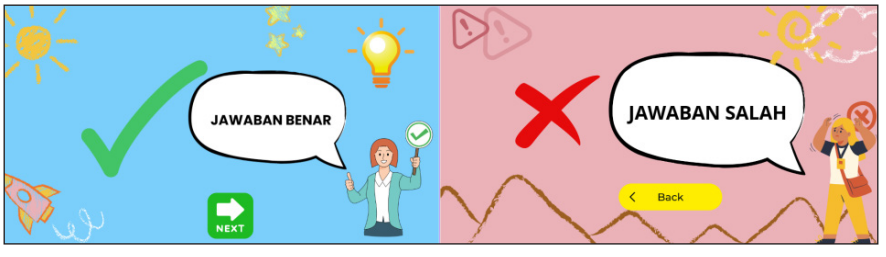

Figure 5. Incorrect and correct answer display

The prototype was made up of complicated multiple-choice questions with pictures and situations that were important to students' everyday lives. The tool was made to include all the parts of the REACT strategy, such as making connections to students' lives, using the strategy in real life, and working together to solve problems. The prototype also has questions of different levels of difficulty, from easy to hard, so that students with different levels of understanding can use it.

Furthermore, validation was carried out by mathematics education experts and linguists to assess the suitability and accuracy of the instrument. Experts provided input related to language, context suitability, and the ability of the questions to measure numeracy literacy in accordance with the desired indicators. Content validity was quantified using Aiken's V formula. A score of $V > 0.80$ was considered valid. From the validation results, some suggestions for improvement were obtained, especially in terms of language clarity and illustrations on some questions to make it easier for students to understand. After improvement, the instrument prototype was reviewed until it met high validity standards and was considered suitable for field testing. The results of mathematics education expert validation are presented in following Table 1.

Based on Table 1, the overall validity score is 0.85 (High Validity). However, based on qualitative feedback, experts suggested minor revisions, such as adding more contextual questions relevant to students' daily lives and increasing the variety of difficulty levels to better measure different depths of understanding. The results of language and linguistic expert validation are presented in following Table 2.

Table 2 shows a high validity score of 0.88 from language experts. Qualitative feedback indicated that while the grammar is precise, compound sentences should be simplified to suit the cognitive level of elementary students. As per an article by Boateng et al. (2021)), the numeracy literacy instrument tested and verified according to REACT is now ready for use in learning as

Table 1
Results of mathematics education expert validation

Validation Aspect	Aiken's V Index	Category
Content Compatibility with the Curriculum	0.85	Valid
Clarity of Language	0.90	Valid
Compatibility with Numeracy Literacy Indicators	0.88	Valid
Accuracy of Difficulty Level	0.80	Valid
Consistency of Assessment	0.83	Valid
Creativity and Innovation of Questions	0.78	Medium Validity
Suitability with REACT Strategy	0.82	Valid
Cognitive Level Appropriateness	0.89	Valid
Contextual Relevance	0.89	Valid
Total Average Validity	0.85	High Validity

Table 2
Results of language and linguistic expert validation

Validation Aspect	Aiken's V Index	Category
Clarity and Precision of Language	0.84	Valid
Use of Math Terms	0.88	Valid
Language Appropriateness for Age	0.92	Valid
Readability of Questions	0.85	Valid
Consistence in Language Style	0.87	Valid
Grammatical Appropriateness	0.89	Valid
Simplicity and Straightforwardness of Language	0.86	Valid
Total Average Validity	0.88	High Validity

this stage of development is finalised. The final prototype of the site was then polished based on the constrained trial results and ready to be implemented in a wider context in the disseminate phase. The results revealed that the results of the develop phase reveal that this instrument has been highly polished and constructed, thus it is an efficient approach to measure the numeracy and literacy skills of students in elementary school who are educated in an environment that is relevant to their own lives.

Stage of Dissemination

At the disseminate stage of the development process of the REACT-based numeracy literacy tool for primary school children, the enhanced tool that can be obtained from the results of earlier trials is subsequently used on a larger group of children to test its validity and reliability in an enlarged context. The goal at this stage is to make the tool measure students' math and reading skills consistently and accurately in a more representative environment. Word gets around by using the tool in a sample of students across different schools and backgrounds to gather representative results. In this application, the instrument is utilised to test the understanding of students on numbers and how they are able to use them in real life, for instance, solving problems in a project-based learning environment. How the instrument is administered is organised in a way in which all the students have an equal chance to try answering the questions. The teacher in charge is also directed to make sure there is proper use of the instrument according to procedures set.

We obtained and analysed data on instrument test scores in SPSS to get an empirical description of how valid and reliable the instrument is. We performed a reliability analysis to find out if the findings were the same for all of the questions in the instrument. We also carried out a validity analysis to validate that each question, in fact, measures aspects of numeracy literacy with respect to the competencies desired. The analysis shows that the tool is consistent because coefficient values are in the normal range. It indicates that the tool consistently measures students' capability. A statistical test was also performed to ascertain how

diverse and challenging the questions were. We also reworded and asked more rigorous questions which were either too simple or too hard to discriminate against. Such an examination ensured that the instrument had a satisfactory mix of questions that could discriminate among students according to ability level and at the correct difficulty level. Such items that are underperformed are flagged and, if necessary, reworded to improve the instrument.

The instrument is then ready to be used as a primary school pupil in mathematics and reading assessment once it is disseminated and interpreted. Especially in the instance of REACT-based education, this is true. The instrument was also shown to teachers so they can provide comments and see how it could be implemented in everyday learning. Teachers who used the instrument on their class lessons testified that the REACT-based problem-solving method facilitateed students to understand and utilise mathematics principles in real life and rendered them more participative and motivated learners. Generally, the result of the disseminate stage shows that this REACT-based numeracy literacy tool is a valuable and trustworthy method for identifying how good the students are at mathematics. Thus, this instrument is now ready to be utilised by numerous individuals to screen numeracy and literacy skills among basic education students. This will improve the quality of education more relevant to the real-life needs of the students. To screen this, REACT-based instrument for numeracy and literacy, researchers perform several tests such as the following:

Validity Test

Validity test results are shown in Table 3. Based on the validity test data of 30 questions tested on 20 students, each question was assessed using Aiken's V method to determine its suitability with the numeracy literacy indicators measured. The Aiken's V value obtained illustrates the validity level of each question, with the following criteria: questions with a score above 0.85 are considered highly valid, indicating that the question is very suitable for the purpose of measurement and does not require improvement. Some questions, such as question numbers 6, 11, 21, and 26, fall into this category, showing validity scores above 0.90 and are considered high quality. Overall, the results of this validity test provide guidance to maintain the questions that have met the standard and improve the questions that are below the threshold so that the overall instrument can provide accurate and reliable results in measuring students' numeracy literacy skills.

Reliability Test

Reliability test results are shown in Table 4. Based on the results of the reliability test on 30 questions tested on 20 students, the reliability value of each question was measured using Cronbach's Alpha coefficient to assess internal consistency. Questions with reliability values above 0.85 are considered highly reliable, indicating that these questions have very high consistency. These questions are recommended to be revised in order to improve the reliability of measurement in the instrument as a whole.

Table 3
Validity test results

Question Number	Validity (Aiken's V)	Description	Question Number	Validity (Aiken's V)	Description
1	0.78	Valid	16	0.80	Valid
2	0.65	Quite Valid	17	0.66	Quite Valid
3	0.82	Valid	18	0.73	Valid
4	0.60	Needs Revision	19	0.65	Quite Valid
5	0.87	Valid	20	0.78	Valid
6	0.90	Very Valid	21	0.91	Very Valid
7	0.75	Valid	22	0.58	Needs Revision
8	0.62	Quite Valid	23	0.85	Valid
9	0.85	Valid	24	0.69	Quite Valid
10	0.68	Quite Valid	25	0.81	Valid
11	0.92	Very Valid	26	0.93	Very Valid
12	0.77	Valid	27	0.76	Valid
13	0.55	Needs Revision	28	0.64	Quite Valid
14	0.88	Valid	29	0.82	Valid
15	0.70	Valid	30	0.67	Quite Valid

Table 4
Reliability test results

Question Number	Reliability (Cronbach's Alpha)	Description	Question Number	Reliabilitas (Cronbach's Alpha)	Description
1	0.82	Reliable	16	0.81	Reliable
2	0.76	Quite Reliable	17	0.72	Quite Reliable
3	0.84	Reliable	18	0.82	Reliable
4	0.69	Needs Revision	19	0.70	Quite Reliable
5	0.88	Very Reliable	20	0.83	Reliable
6	0.91	Very Reliable	21	0.90	Very Reliable
7	0.80	Reliable	22	0.66	Needs Revision
8	0.74	Quite Reliable	23	0.85	Reliable
9	0.85	Reliable	24	0.73	Quite Reliable
10	0.77	Quite Reliable	25	0.87	Reliable
11	0.89	Very Reliable	26	0.92	Very Reliable
12	0.83	Reliable	27	0.81	Reliable
13	0.68	Needs Revision	28	0.75	Quite Reliable
14	0.86	Reliable	29	0.83	Reliable
15	0.79	Quite Reliable	30	0.78	Quite Reliable

Overall, the results of this reliability test provide an overview of which questions are consistent and can be used, and which questions require revision to improve the quality of the instrument in measuring students' numeracy literacy.

Internal consistency reliability was evaluated at the instrument level using Cronbach's Alpha coefficient rather than at the individual item level. The overall Cronbach's Alpha coefficient obtained for the instrument exceeded the commonly accepted threshold of 0.85, indicating satisfactory internal consistency among the assessment items. Item-level evaluation was conducted using corrected item-total correlation and item discrimination analyses to determine the contribution of each item to the overall scale consistency.

Discriminating Power Test

Discriminating power test results are shown in Table 5. Based on the results of the differentiating power test on 30 questions tested on 20 students, the differentiating power value is obtained which demonstrates the extent to which each question is able to distinguish students with high and low abilities. Questions with a differentiating power value above 0.60, such as question numbers 5, 6, 11, 21, and 26, are categorised as demonstrate proficiency in differentiating student ability levels. These questions demonstrate a very strong ability to identify differences in ability between students. Questions with differentiating power values between 0.40 to 0.59, such as question numbers 1, 3, 7, and 23, are considered good. These questions have met the criteria

Table 5
Discriminating power test results

Question Number	Discrimination Index	Description	Question Number	Reliability (Cronbach's Alpha)	Description
1	0.45	Good	16	0.81	Reliable
2	0.30	Mediocre	17	0.72	Quite Reliable
3	0.52	Good	18	0.82	Reliable
4	0.25	Poor	19	0.70	Quite Reliable
5	0.60	Excellent	20	0.83	Reliable
6	0.65	Excellent	21	0.90	Very Reliable
7	0.40	Good	22	0.66	Needs Revision
8	0.28	Mediocre	23	0.85	Reliable
9	0.55	Good	24	0.73	Quite Reliable
10	0.32	Mediocre	25	0.87	Reliable
11	0.62	Excellent	26	0.92	Very Reliable
12	0.47	Good	27	0.81	Reliable
13	0.20	Poor	28	0.75	Quite Reliable
14	0.50	Good	29	0.83	Reliable
15	0.35	Mediocre	30	0.78	Quite Reliable

of being sufficient to differentiate between high and low ability students, so they can be used without significant revision.

Overall, the results of this differentiating power test provide information about the quality of the questions in differentiating students' abilities. Questions in the good and excellent categories can be used directly, while the ones with sufficient and insufficient differentiating power require adjustments in order to function optimally in measuring students' numeracy literacy skills.

Level of Difficulty Test

Levels of difficulty test results are revealed in Table 6. A test with thirty questions ranging in difficulty from extremely difficult to very easy was administered to twenty students. The results demonstrate the breadth of topics covered by the questions. Questions with difficulty scores below 0.40, such as 4, 8, 13, 17, 22, and 24, are deemed challenging. Only a small percentage of students correctly answer these questions, indicating that they are extremely difficult. The results of this difficulty make it evident which questions need to be revised or adjusted to better balance the easy and hard categories. Too-easy or too-hard questions must be changed in order for the assessment tool to fairly evaluate students' general proficiency. While questions that are too easy or too difficult should be revised, moderate-level questions can be used directly. Items with lower discrimination indices (e.g., Items 4, 13, 22) often require 'Transferring' knowledge to novel situations, a cognitively demanding REACT phase. This

Table 6
Results of the level of difficulty test

Question Number	Difficulty Level	Description	Question Number	Difficulty Level	Description
1	0.70	Medium	16	0.72	Medium
2	0.85	Easy	17	0.38	Difficult
3	0.55	Medium	18	0.63	Medium
4	0.40	Difficult	19	0.82	Easy
5	0.65	Medium	20	0.54	Medium
6	0.90	Easy	21	0.88	Easy
7	0.50	Medium	22	0.42	Difficult
8	0.35	Difficult	23	0.77	Medium
9	0.75	Medium	24	0.32	Difficult
10	0.80	Easy	25	0.69	Medium
11	0.45	Difficult	26	0.90	Easy
12	0.60	Medium	27	0.56	Medium
13	0.30	Difficult	28	0.36	Difficult
14	0.78	Easy	29	0.74	Medium
15	0.68	Medium	30	0.80	Easy

suggests that students struggle with applied transfer, highlighting an area for targeted instructional focus. Conversely, items aligned with 'Experiencing' and 'Applying' showed higher engagement and success rates, indicating that contextual familiarity enhances performance. Furthermore, the correlation between difficulty levels and REACT components reveals that tasks involving 'Cooperating' and 'Transferring' consistently presented greater challenges, whereas 'Relating' to familiar contexts generally yielded higher success.

Validity and Psychometric Quality of the REACT-Based Numeracy Literacy Instrument

The present study aimed to develop and validate a digital numeracy literacy assessment instrument grounded in the REACT (Relating, Experiencing, Applying, Cooperating, and Transferring) framework for elementary school students. The findings demonstrate that the developed instrument possesses satisfactory psychometric properties, including high content validity, acceptable item validity, appropriate levels of item difficulty and discrimination, and strong internal consistency. Collectively, these findings indicate that the instrument is capable of measuring contextual numeracy literacy in a valid and reliable manner while maintaining item characteristics appropriate for elementary learners. More importantly, the psychometric evidence suggests that the REACT framework can be operationalised into measurable assessment constructs without compromising measurement quality. This finding is particularly significant because previous studies have primarily investigated REACT as a pedagogical approach to improve mathematics learning, whereas limited attention has been devoted to its application as the conceptual foundation of educational assessment (Faqih et al., 2022; Utama et al., 2023). Consequently, the present study extends the existing literature by demonstrating that REACT is not only effective for organising classroom instruction but also suitable for guiding the systematic development of contextualised assessment instruments.

The high content validity obtained through expert evaluation indicates that the assessment of items adequately represents the intended dimensions of contextual numeracy embedded within the REACT framework. The consistent agreement among expert validators suggests that the developed indicators successfully translate abstract learning principles into observable assessment tasks appropriate for elementary school students. This finding supports previous studies emphasising that contextual mathematics learning becomes more meaningful when mathematical concepts are closely connected with students' daily experiences and authentic situations (Faqih et al., 2022; Muliani et al., 2022; Utama et al., 2023). However, the contribution of the present study differs from these earlier investigations in an important respect. Previous studies primarily examined how REACT enhances students' learning outcomes through instructional activities, whereas the current study demonstrates

that the same theoretical principles can be transformed into measurable assessment indicators. Thus, the role of REACT is expanded from an instructional model into a conceptual framework for educational assessment, enabling contextual numeracy competencies to be represented more systematically during the measurement process.

The item analysis further strengthens the quality of the developed instrument. The satisfactory item validity coefficients indicate that individual assessment items consistently contribute to measuring the overall construct of contextual numeracy literacy. Likewise, the combination of acceptable discrimination indices and predominantly moderate difficulty levels demonstrates that the instrument effectively differentiates students with varying levels of numeracy competence while avoiding items that are either excessively easy or excessively difficult. Such balanced psychometric characteristics are essential for educational assessments because they improve the accuracy of student classification and provide more dependable information regarding students' mathematical abilities. These findings are consistent with previous studies on numeracy instrument development, which emphasise that well-functioning assessment items should simultaneously demonstrate acceptable validity, discrimination, and difficulty characteristics to ensure accurate measurement of students' competencies (Hamdu et al., 2023; Muliani et al., 2022). The present results therefore confirm that contextualised assessment items can achieve satisfactory psychometric quality while maintaining authentic mathematical contexts.

The overall internal consistency of the developed instrument further supports its suitability for assessing elementary school students' numeracy literacy. High internal consistency indicates that the assessment of items collectively measures a coherent construct rather than functioning as isolated questions. This finding is particularly important because the instrument integrates five interrelated dimensions of the REACT framework, each representing different aspects of contextual learning. Despite measuring multiple learning processes, the obtained reliability evidence suggests that these dimensions operate cohesively as components of a broader contextual numeracy construct. This result strengthens the conceptual assumption that contextual numeracy literacy is multidimensional but internally integrated, encompassing students' abilities to relate prior knowledge, engage in authentic experiences, apply mathematical concepts, collaborate in problem solving, and transfer knowledge to unfamiliar situations. Consequently, the psychometric evidence supports not only the technical quality of the instrument but also the coherence of the underlying theoretical framework.

Beyond demonstrating acceptable measurement properties, the findings also provide evidence regarding the feasibility of integrating contextual learning theory into educational assessment design.

Traditionally, assessment development has focused primarily on measuring cognitive outcomes through procedural or contextual problem-solving tasks. In contrast, the present instrument was intentionally designed to represent broader learning-oriented competencies embedded within the REACT framework. This design approach allows assessment items to capture not only students' mathematical performance but also the cognitive processes associated with meaningful learning experiences. Such an approach aligns with the argument that authentic assessment should represent the processes through which knowledge is constructed rather than merely documenting the correctness of final answers. Therefore, the satisfactory psychometric performance observed in this study suggests that contextual learning principles can be operationalised into educational measurement without sacrificing technical assessment quality.

Taken together, these findings provide empirical support for the development of contextualised digital numeracy assessment instruments that integrate learning theory and educational measurement. While previous research has successfully demonstrated the instructional effectiveness of REACT-based learning environments (Faqih et al., 2022; Utama et al., 2023), the present study extends this body of knowledge by validating REACT as a viable framework for assessment development. Accordingly, the contribution of this study extends beyond the production of a valid and reliable digital instrument. It also demonstrates that contextual learning principles can serve as measurable assessment constructs, thereby strengthening the conceptual relationship between contextual pedagogy and educational assessment. This extension is particularly relevant for elementary mathematics education, where meaningful assessment should capture not only what students know but also how they construct, apply, and transfer mathematical understanding across authentic contexts.

REACT as a Framework for Contextualised Numeracy Assessment

One of the most important findings of this study is that the REACT framework can be extended beyond its conventional role as an instructional strategy to function as a conceptual framework for educational assessment. Previous studies have consistently reported that REACT improves students' mathematical achievement, conceptual understanding, problem-solving ability, and learning motivation because mathematical concepts are introduced through authentic experiences and meaningful contexts (Faqih et al., 2022; Utama et al., 2023). However, these investigations have primarily evaluated REACT from the perspective of instructional effectiveness, using assessment merely as an instrument for measuring learning outcomes. Consequently, relatively little attention has been devoted to examining how the conceptual dimensions of REACT can be operationalised into measurable assessment constructs. The present study addresses this gap by demonstrating that the five dimensions of REACT—Relating,

Experiencing, Applying, Cooperating, and Transferring—can be systematically translated into assessment indicators capable of measuring contextual numeracy competencies. Therefore, this study extends previous research by positioning REACT not only as a pedagogical approach but also as a framework for designing authentic educational assessment.

This conceptual shift has important implications for the way contextual numeracy is assessed. Conventional numeracy assessments generally emphasise students' ability to solve contextual mathematical problems through individual cognitive performance. Such assessments provide valuable information regarding procedural competence, mathematical reasoning, and problem-solving ability. Nevertheless, the findings of the present study suggest that contextual numeracy encompasses broader competencies than those represented by conventional cognitive assessments alone. Through the integration of REACT, the developed instrument captures students' abilities to connect prior experiences with new mathematical concepts, construct understanding through authentic activities, apply knowledge in meaningful situations, collaborate in mathematical reasoning, and transfer acquired knowledge to unfamiliar contexts. Consequently, contextual numeracy is represented not merely as the ability to produce correct answers but as the capacity to engage in the cognitive and social processes through which mathematical understanding is developed. This broader conceptualisation supports current perspectives emphasising that authentic assessment should capture meaningful learning processes in addition to learning outcomes.

The findings also provide an opportunity to reconsider the relationship between contextual learning and educational assessment. Existing studies involving contextual mathematics learning have generally assumed that improvements in contextual understanding are adequately reflected by students' performance on contextualised test items (Muliani et al., 2022; Utama et al., 2023). While this assumption remains valid, the present findings indicate that contextual assessment can be strengthened by explicitly incorporating the learning dimensions responsible for generating contextual understanding. Rather than treating context solely as the setting in which mathematical problems are presented, the proposed instrument operationalises context as a multidimensional learning environment in which students activate prior knowledge, engage with authentic experiences, collaborate with peers, apply mathematical reasoning, and demonstrate knowledge transfer. Accordingly, assessment becomes more closely aligned with the processes through which mathematical competence is developed, thereby strengthening the authenticity of contextual numeracy measurement.

Another important contribution of this study concerns its relationship with existing large-scale numeracy assessments, particularly Indonesia's Minimum

Competency Assessment (AKM) and the programme for International Student Assessment (PISA). Both assessment systems have significantly influenced contemporary numeracy assessment by emphasising the application of mathematical knowledge in authentic real-world situations. Their contextual orientation has encouraged schools to move beyond procedural computation toward mathematical reasoning and everyday problem solving. Nevertheless, contextualisation within these frameworks is primarily reflected in the design of realistic mathematical tasks, while the experiential and collaborative processes through which students construct contextual understanding remain largely outside the measurement framework. Consequently, these assessments predominantly evaluate the outcomes of contextual reasoning rather than the broader learning processes that support contextual mathematical competence.

The present study does not seek to replace existing assessment frameworks such as AKM or PISA. Instead, it complements and extends their conceptual orientation by embedding the REACT dimensions directly into assessment design. In the developed instrument, contextual situations serve not merely as realistic problem settings but as opportunities for students to demonstrate how they relate mathematical ideas to prior experiences, construct meaning through authentic engagement, collaborate in reasoning, apply mathematical concepts, and transfer understanding across different contexts. This multidimensional representation allows assessment to capture competencies that are less explicitly represented in conventional numeracy instruments. Consequently, the contribution of the proposed instrument lies not in introducing an alternative definition of numeracy, but in expanding how contextual numeracy can be represented and measured within elementary educational assessment.

These findings also respond to ongoing discussions regarding authentic assessment in elementary mathematics education. As educational systems increasingly emphasise higher-order thinking, meaningful learning, and contextual problem solving, assessment instruments are expected to provide richer evidence regarding students' learning processes rather than merely documenting achievement scores. The satisfactory psychometric performance obtained in the present study indicates that incorporating contextual learning dimensions into assessment design does not compromise measurement quality. Instead, integrating REACT provides additional diagnostic information regarding students' strengths and challenges across multiple dimensions of contextual numeracy. Such information may support teachers in identifying whether students experience difficulties in connecting prior knowledge, applying mathematical concepts, collaborating during problem solving, or transferring mathematical understanding to new situations. Therefore, the assessment has potential value not only as an evaluative instrument but also as a diagnostic tool for improving mathematics instruction.

From a theoretical perspective, the present findings contribute to the growing body of literature seeking stronger alignment between learning theory and educational assessment. Previous research has demonstrated that contextual learning environments improve mathematical understanding because they encourage students to construct knowledge actively through meaningful experiences (Faqih et al., 2022; Muliani et al., 2022; Utama et al., 2023). The present study extends this perspective by demonstrating that the same theoretical principles can also guide the development of assessment instruments capable of representing contextual learning processes. Consequently, the contribution of this study extends beyond instrument development itself. It proposes an alternative conceptual perspective in which educational assessment is viewed as an extension of learning theory rather than merely a mechanism for evaluating learning outcomes. Such integration strengthens the conceptual foundation of authentic numeracy assessment and contributes to the continuing evolution of educational assessment frameworks designed for elementary mathematics education.

Theoretical Contribution, Practical Implications, Limitations, and Future Directions

Beyond establishing the psychometric adequacy of the developed instrument, the present study offers a broader contribution to the field of educational assessment by strengthening the conceptual relationship between contextual learning theory and educational measurement. Previous studies concerning REACT have consistently demonstrated its effectiveness in improving mathematics learning outcomes, conceptual understanding, and student engagement (Faqih et al., 2022; Muliani et al., 2022; Utama et al., 2023). Nevertheless, these investigations have predominantly viewed REACT as an instructional strategy designed to facilitate classroom learning. The present study extends this perspective by demonstrating that the conceptual principles underlying REACT can also guide the development of assessment instruments capable of representing multidimensional contextual numeracy competencies. Accordingly, this study contributes to educational assessment by proposing that authentic assessment should not merely evaluate mathematical performance but should also represent the learning processes through which mathematical competence is constructed, applied, and transferred. This conceptual extension broadens the existing understanding of contextual numeracy assessment and provides an alternative perspective for future instrument development research.

Another important contribution concerns the conceptualisation of contextual numeracy itself. Conventional numeracy assessments generally conceptualise numeracy as students' ability to interpret quantitative information, apply mathematical reasoning, and solve contextual problems individually. While these competencies remain fundamental, the findings of this

study suggest that meaningful numeracy development also depends upon learners' abilities to connect mathematical concepts with prior experiences, construct understanding through authentic activities, collaborate during mathematical reasoning, and transfer acquired knowledge across different situations. By operationalising these dimensions into measurable assessment indicators, the proposed instrument expands the representation of contextual numeracy beyond procedural accuracy and contextual reasoning alone. Consequently, the developed assessment provides a more comprehensive representation of mathematical competence that aligns more closely with contemporary perspectives emphasising meaningful, authentic, and student-centered learning.

The findings likewise have important implications for classroom assessment practices in elementary education. Teachers frequently rely on assessment instruments that primarily report whether students answer mathematical questions correctly, providing limited diagnostic information regarding the learning processes underlying students' performance. In contrast, the REACT-based instrument developed in this study enables teachers to obtain richer evidence regarding different aspects of contextual numeracy competence. Because the assessment items are systematically designed around the dimensions of Relating, Experiencing, Applying, Cooperating, and Transferring, teachers are able to identify more specifically which aspects of contextual mathematical learning require additional instructional support. For example, students may demonstrate adequate procedural calculation skills while experiencing difficulty transferring mathematical knowledge to unfamiliar situations or collaborating effectively during contextual problem solving. Such diagnostic information may assist teachers in designing more targeted instructional interventions and strengthening the alignment between assessment and classroom learning activities.

The digital implementation of the assessment instrument also provides practical advantages for elementary mathematics education. Digital assessment facilitates more efficient administration, scoring, and data management while reducing teachers' administrative workload. In addition, digital platforms provide opportunities for immediate feedback and systematic monitoring of students' numeracy development across different learning dimensions. These characteristics are particularly relevant as schools increasingly integrate digital technologies into teaching and assessment practices. Therefore, the present study contributes not only to contextual numeracy assessment but also to the broader movement toward technology-enhanced assessment capable of supporting evidence-based instructional decision making. The integration of contextual learning principles with digital assessment thus represents a promising direction for improving both the quality and efficiency of elementary mathematics assessment.

Despite these contributions, several limitations should be acknowledged when

interpreting the findings. First, the field testing was conducted with elementary school students from a limited geographical area, which may restrict the generalisability of the instrument to other educational contexts with different curricular, cultural, or demographic characteristics. Second, although the instrument demonstrated satisfactory content validity and internal consistency, the psychometric evaluation focused primarily on preliminary instrument development procedures, including item validity, discrimination, difficulty, and reliability analyses. Additional validation using larger and more diverse samples would further strengthen the evidence supporting the instrument's measurement properties. Third, the present study evaluated the psychometric quality of the instrument but did not investigate its long-term impact on students' learning outcomes or teachers' assessment practices following sustained classroom implementation. Consequently, the reported findings should be interpreted within the scope of instrument development rather than instructional effectiveness.

Building upon these limitations, several directions for future research emerge. Future studies may examine the applicability of the REACT-based assessment across different grade levels, regions, and educational systems to evaluate the consistency of its psychometric properties under more diverse learning conditions. Further investigations may also employ more advanced psychometric techniques, such as exploratory or confirmatory factor analysis and item response theory, to examine the dimensional structure of the instrument and strengthen construct validation. In addition, longitudinal studies investigating how REACT-based assessment supports the development of contextual numeracy over time would provide valuable evidence regarding its educational impact. Finally, integrating adaptive digital assessment features, automated feedback, and learning analytics may further enhance the diagnostic capabilities of the instrument while supporting more personalised mathematics learning experiences for elementary school students.

Overall, the findings of this study demonstrate that contextual learning principles embodied within the REACT framework can be successfully translated into a psychometrically sound digital assessment instrument for elementary numeracy literacy. More importantly, the study illustrates that educational assessment can move beyond measuring isolated mathematical outcomes toward representing the broader cognitive, experiential, collaborative, and transferable processes through which mathematical competence develops. By integrating contextual learning theory with educational measurement, the proposed instrument contributes both practically and theoretically to the continuing development of authentic numeracy assessment. Consequently, the present study not only provides an empirically validated assessment instrument for elementary mathematics education but also offers an alternative conceptual direction for future research concerning contextualised educational assessment.

CONCLUSION

This study investigates how a numeracy literacy tool was developed based on the REACT (Relating, Experiencing, Applying, Cooperating, and Transferring) learning strategy, which is particularly created for Indonesian primary school students. In 21st-century education, being numerate and literate, such as being critical, analysing, and problem-solving, is extremely important. The tool was developed in four stages: define, design, develop and validate, and finally, publish it. Each stage checks that the tool is consistent with the national curriculum, feasible in the students' lives, and can facilitate them to improve their mathematics abilities.

Development results indicate that the REACT approach can be used to facilitate students better understanding mathematical concepts by connecting what they learn in math class to life's situations and activities. The test is comprised of difficult multiple-choice questions that assess students' overall knowledge, including the ability to critically analyse and use what they learn to apply in real life. The validity and reliability of the tool were confirmed by math and language teachers and were highly found to be reliable. The test can be conducted in basic education environments. Field tests were also carried out in some schools to acquire real data that would confirm that the instrument is valid and reliable in measuring the ability of the students.

Practically, this instrument serves not only as an assessment tool but also as a diagnostic aid for teachers to identify specific student difficulties in the 'Applying' and 'Transferring' stages of learning. For future research, it is recommended to conduct a longitudinal study to analyse whether the use of this REACT-based instrument significantly improves students' long-term retention of numeracy concepts compared to traditional static assessments. Additionally, further development could integrate adaptive algorithms to tailor the question of difficulty automatically based on student responses.

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Applying the STEAM Integrated Project-Based Learning Model: Improving 21st Century Learning Outcomes and Skills

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ABSTRACT

This research aims to determine the effectiveness of the learning model of STEAM-integrated PjBL. The research aim is helping the learning process of students. This research was conducted at elementary schools in Malang city by taking two schools as samples, namely SDN Bareng 3 and SDN Dadaprejo 2. There were 27 grade V students who were used as samples in this study. The present investigation was conducted upon the Quasi Experiment Design with a control group. The results of the research conducted show that the application of the PjBL-based STEAM method is able to increase student learning achievement. This is evidenced by an increase in the average value of pre-STEAM implementers and after implementation. The average score of students before the implementation of PjBL-based STEAM was 48.02 and increased to 82.05 after the implementation of STEAM PjBL. The analysis of the data with t-test and effect size found that the STEAM-integrated PjBL improves the student learning outcomes to be in moderate influence. Additionally, the validity and reliability test results of the research instruments indicate that the measuring instruments used in this study are valid and reliable. We can say that the implementation of STEAM in PjBL can increase student academic achievement in elementary school. The results of this study provide a rationale for implementing innovative learning approaches to help students in Indonesia improve their communication, collaboration, and critical thinking skills, which are important aspects of 21st century skills.

Keywords: 21st century skills, basic education, learning outcomes, PjBL, STEAM

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INTRODUCTION

Research conducted in the last five years suggests that Students are expected to be able to improve their ability to face the 21st century with situations related to Volatility, Uncertainty, Complexity, and Ambiguity (VUCA) in the future. (Mohanta et al., 2019; Seow et al., 2019). The skills that are expected to appear in students are the ability to think critically, collaborate, be creative, and have good communication patterns. Today, these skills are the main thing needed to face the challenges of future jobs (Alismail, 2023; Bayley, 2022; Bray et al., 2023; Kaya et al., 2023; Peña-Ayala, 2021). Referring to these conditions, it is known that in Indonesia and several other developing countries, students still do not have the ability to think critically and creatively to compete at the global level. Learning in Indonesia has not yet penetrated into studies in general related to the job market that place analytical & creative thinking, AI, data literacy, and lifelong learning. The lack of a learning process that integrates this will make students not have the skills or competencies to compete globally. What should be done is to integrate the learning process with future needs in the form of *analytical & creative thinking skills*, *AI and data literacy through initial training in schools* (Dumitru & Halpern, 2023; Pandit et al., 2025).

Referring to this, the integration of these skills is important in the learning process because education aims to prepare students to face various global challenges and changing times (Borroni et al., 2021; Chen et al., 2023; Colim et al., 2022; Johnsen et al., 2024; Loyens et al., 2023; Qi et al., 2022; Santhosh et al., 2023). Therefore, educational paradigms must shift to foster these competencies, moving beyond rote memorisation to cultivate deeper understanding and practical application of knowledge (An, 2020).

The current study found that only 30% of students at the primary school level in Indonesia have basic competencies and the ability to collaborate based on global standards. This achievement is much smaller than OECD countries with an average achievement of 70%. This shows that the quality of education can hinder students' potential to compete in the global world in the future. To address this disparity, innovative pedagogical approaches are crucial for fostering essential 21st-century skills among students, particularly in developing nations (Huijser et al., 2015)

In addition, some literature found shows that some developed countries have successfully integrated STEAM education (Science, Technology, Engineering, Arts, Mathematics) with PjBL (Project-based Learning). Students' ability to analyse and be creative has increased significantly after implementing the integration of STEAM and PjBL (Chistyakov et al., 2023; Hawari & Noor, 2020; Megawati, 2024). However, in Indonesia, the process of implementing various education models is still uneven. The implementation is constrained by the lack of subject teacher resources and the inadequate training received by teachers. Several studies conducted show that Indonesia has

attempted to integrate various learning models that are relevant to the needs and development of students. These models include culture-based learning, technology-integrated learning, and approaches that focus on developing students' emotional intelligence. These models are believed to have a significant impact on student development and education in Indonesia as a whole (Jalaluddin et al., 2020; L. M. Kasmini, 2020; Mardhatillah et al., 2020).

LITERATURE REVIEW

Despite these efforts, challenges persist in the equitable and effective implementation of these innovative pedagogies across all regions and educational tiers in Indonesia, highlighting a gap between policy aspirations and practical classroom realities (Prahanı et al., 2023). The consistently low PISA scores in Indonesia, exacerbated by the recent pandemic, underscore the urgent need for effective pedagogical shifts, with Project-Based Learning being a promising approach to cultivate critical thinking and problem-solving skills across all educational levels (Khusna et al., 2022). Despite the government's initiatives to modernise education through internet access and online learning platforms like SPADA Indonesia, the overall quality and global competitiveness of Indonesian students remain a significant concern, necessitating a re-evaluation of current educational strategies (Ra et al., 2021; Samala et al., 2024; Thohir et al., 2021). One promising avenue is the integration of Project-Based Learning within the "Freedom to Learn" framework, which aligns with the goal of producing graduates who can adapt to evolving scientific and technological demands and societal dynamics (Camillo Lento, 2016).

Especially in Malang City, innovations in education have been implemented in various aspects of learning. SDN Bareng and SDN Dadaprejo 2 are among the schools that have successfully implemented learning with the latest innovations. Initial analysis conducted in these two schools showed that the teaching materials and teaching books are applied by the teacher and students not proven to be significantly effective in improving students' skills and development in high-level thinking. The findings conclude that there is an urgent need to implement a learning model that integrates 21st century skills holistically and systematically. The learning approach should be designed by integrating 21st century competencies that are relevant and appropriate to the needs of students and the times (González-Pérez & Ramírez-Montoya, 2022; González-Salamanca et al., 2020). This necessity is particularly pressing given Indonesia's rapidly increasing internet penetration and extensive use of social media, underscoring the potential for technology-enhanced educational approaches (Ra et al., 2021). The "Merdeka Belajar" programme, implemented by the Indonesian Ministry of Education and Culture, aims to address these educational challenges by promoting flexible learning and fostering creativity and innovation among students and educators alike (Sihombing et al., 2021).

This initiative aligns with the principles of 21st-century learning, emphasising student-centred approaches to cultivate critical thinking, collaboration, creativity, and communication skills (Hunaepi & Suharta, 2024; Sihombing et al., 2021). However, challenges persist in fully realising the programme's potential due to varying levels of teacher readiness and unequal access to facilities, especially between urban and rural areas (Mardhatillah, 2017; Samala et al., 2024). Therefore, further research is needed to explore the effectiveness of integrating Project-Based Learning with a focus on 21st-century skills within the "Merdeka Belajar" framework, particularly in diverse educational settings across Indonesia. This approach would facilitate the development of analytical thinking, problem-solving, and collaborative abilities essential for navigating complex real-world scenarios, thereby aligning with the broader goals of educational reform (Ace, 2007; Hidayatullah et al., 2021). Such an integration could also bolster the development of independent learning and critical thinking skills, which are crucial for students' academic and future career success (Aliftika et al., 2021). Moreover, addressing teachers' initial perspectives and providing systemic support for their professional development is crucial for the continuous success of such innovative educational policies (Thohir et al., 2021). The Merdeka Belajar-Kampus Merdeka policy, for instance, explicitly promotes student-centred learning and aims to cultivate competencies and skills relevant for future careers by emphasising critical thinking, problem-solving, collaboration, and creativity (Astuti et al., 2023).

This study was conducted to fill the gap of previous research by analysing the effectiveness of the STEAM-integrated Project-Based Learning (PjBL) model to improve student learning outcomes. The model is targeted to improve students' understanding academically and also strengthen adaptability to future learning challenges. Currently, the teaching and learning process experiences various challenges in the form of developing diverse learning media, student involvement in problem solving, and developing student potential according to their field of study. It is hoped that the focused development and appropriate application of methods in this research will make a worthy contribution to the global education literature and support the advancement of educational practices in Indonesia, especially basic education (Ananda et al., 2023; Kasmini et al., 2024).

METHODOLOGY

This research was conducted using a Quasi-Experiment Design Method. The practice is a type of field experiment that uses a control class group, even though its control over extraneous variables that influence the application of the experiment is not complete. This research design is based-on Nonequivalent Control Group Design, as illustrated in Figure 1:

Variables in this research include the independent and dependent variables known as the X and Y variables.X variable is the independent variable which is the PjBL

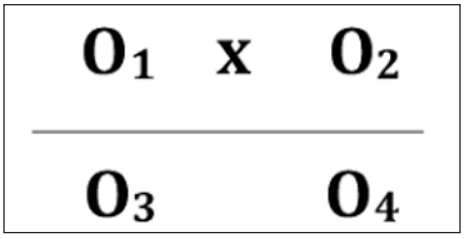

Figure 1. Nonequivalent control group design
Information:
O_1 and O_3 = Pre-Test (Test 1) of the control and experimental class groups.
X = Learning based on the STEAM integrated PjBL learning model.
O_2 and O_4 = Post-Test Measurements of the control and experimental group respectively

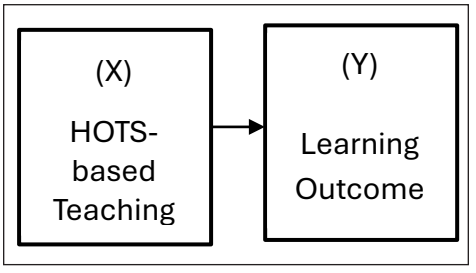

Figure 2. Research variables

learning model integrates the STEAM approach. The bound variable in this study, or also called the dependent variable, is the learning outcomes. These variables are illustrated in Figure 2.

The data of this research was conducted at BE 3 and DP 2 State elementary school. This study was conducted on the period 08-30 August 2024. Sampling was carried out using purposive sampling techniques, taking into account several criteria, including the curriculum used in schools, students' initial abilities, distance, and cooperation carried out by researchers with schools in Malang City. Referring to these criteria, the schools used as the location of the research are SD Negeri 3 Bareng and SD Negeri 2 Dadaprejo Malang City. The research was conducted in grade 5 (five) who were considered to have sufficient reasoning skills for the implementation of the research. The number of students who became the sample was 27 students consisting of 15 students at SD Negeri 3 Bareng as an experimental class and 12 students at SD Negeri 2 Dadaprejo as a control class.

Three forms of testing, documentation, and observation are dimensions of the method with which the data are collected in this study. Tests are used to measure the impact of improvement plan on the success of student learning, for example with test to describe process or performance quantitatively by gathering a factual data, such as Pretest (‘test before’) and Posttest (‘test after’) tests given to working and experimental group. There are 30 indicators used to assess that are developed by the researcher, but in Pre-Test and Post-Test there are only 24 data or points that are considered reliable and valid. Documentation: This is the way data referred to the process and outcomes of learning are recorded and kept (e.g. descriptions of the activities and materials used in the experiment). There was observation where qualitative information from the manner in which the students were engaging with the learning model and their enjoyment and engagement was gathered. There is also a questionnaire for observers to measure the level of effectiveness of the implementation of the STEAM integrated PjBL learning model to improve students’ learning outcomes.

The data in this study were analysed using the latest version of the Statistical Package for Social Sciences (SPSS) application. The validities, reliability, and homogeneities of the factors were investigated through Fisher's test. Normality tests are conducted and checked using Lilliefors test process. The data was also tested using Effect size and N-Gain analysis, including hypothesis testing with the t-test.

The normalised gain formula uses the following two calculation steps for the students' learning output improvement, with the interpretation criteria presented in Table 1:

$$\text{Normalised Gain (ng)} = \frac{posttest\ \ score\ -pretest\ \ score}{ideal\ \ score\ -pretest\ \ score}$$

Table 1
Normalised gain interpretation (ng) modified

Interpretation	Value
Decline	-1.00 ≤ng> 0.00
No increase	ng = 0.00
Low	0.00 <ng< 0.30
Keep	0.30≤ ng <0.70
Tall	0.70 ≤ng≤ 1.00

The criteria used for determining the effect size can be divided into several categories, each serving a specific purpose in evaluating the magnitude and significance of the effects, as presented in Table 2:

Table 2
Category: Effect size (es)

Category	Value
Small	es < 0.2
Keep	0.2 <es <0.8
Tall	es> 0.8

Before being used for research, the validity and reliability of the instrument must be tested first, so that it is proven valid and reliable as a tool to measure student learning outcomes. In this case, the instrument item is said to be valid if the significance value is less than 0.05 (sig<0.05), the instrument item is said to be invalid if the significance value is greater than 0.05 (sig>0.05). The results of the test for the validity of the indicator items are given as following:

Table 3
Results of the validity test

No	Value	Interpretation
1,2,4,5,6,8,9,10, 11,13,14,15,19	0.000	Valid
3,7,12,20	0.001	Valid
16	0.995	Not Valid
17	0.779	Not Valid
18	0.983	Not Valid

The validity test of the question items to be applied to students was found as shown in Table 3. There are 17 questions that have a significance value below 0.05 and are considered valid. Meanwhile, three questions had a significance value above 0.05 and were considered invalid. Referring to that, only 17 questions were applied to students to test students' abilities through the pretest and posttest. The questions were validated by learning instrument experts at the State University of Malang.

Tests, in themselves, are not reliable unless their reliability is high. A test must be reliable to be valid, but it can be reliable without always being valid. The reliability

of the indicators to measure the variables used was verified by the reliability test based on the cronbach alpha formula. Reliability data for the Cronbach alpha of an instrument is reliable at 0.60 and above. (Sugiyono, 2019). The following is a display of the results of the reliability test of the research instrument:

Table 4
Reliability statistics

Number of Items	Value
17	0.732

Table 4 shows that the reliability test for the research instrument exam questions yielded an r11 value of 0.732, which exceeds the acceptable threshold of 0.60 (0.732 > 0.60). This indicates that high reliability measures have been achieved. Additionally, the appraisal instrument for evaluating student learning outcomes (ECAs) in relation to teacher assessment reliability is reflected in the results found in Table 5.

Following the validity and reliability assessments for the 20 learning outcome questions, the researcher decided that 17 of these questions would be utilised in the final hypothesis test. The three questions that did not meet the dispersion criteria were excluded. Consequently, this research will focus on the following questions: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 19, and 20. Based on the validity and reliability testing results, these 17 items are regarded as having met a high standard and are considered suitable for measuring student learning outcomes.

RESULTS

The results of pretest and posttest of the experimental and control class are obtained that the achievement of the students is higher when is taught using STEAM integrated Project-Based Learning (PjBL) model. Research findings were indicated that the mean scores of students well in control and experimental groups were rising from their pretests to their posttest. The pre- and posrater and control class group were rated: Control group in the pre-post scores summations and test summary.

Table 5
Recapitulation of pretest and posstest scores

Indicator	Class			
	Experiment		Control	
	Pretest	Posstest	Pretest	Posstest
Total Value	825	1395	795	1195
Average	48,52	82,05	46,76	70,29

Referring to the table data, a clearer graphical picture of the results of the students' pretest and posttest can be produced. The following is a graph of the results of the student pretest and posttest research, as shown in Figure 3:

The findings indicated that the mean score of pretest and posttest in the experimental class has a higher value compared to the control class, as depicted by the graph above. The mean score of pretest in the eksperimental class was 48.52 and in the control group was 46.76. Experimental class average for posttest was 82.05 compared to 70.29 control class average.

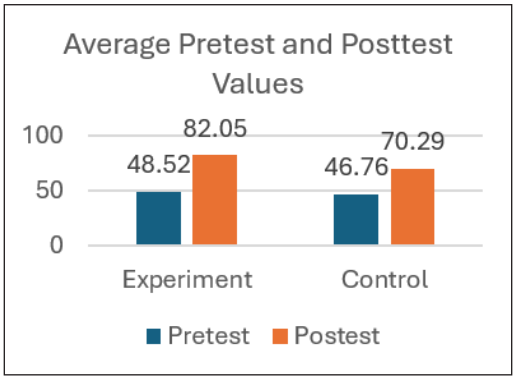

Figure 3. Average pretest and postest value

Refers to the results of student tests for the pretest and posttest in the experimental class that has rised significantly is shown that the STEAM integrated PjBL learning model can improve the students learning outcomes.

Normality Test

The data analysis required test is the test on the requirements or on the assumptions such as the normality test. But this is the thing that normalilty checks on data for the dealer should be done prior to of statistical distributions tests (i.e., regression analysis). Uniform data is good data. Kolmogorov-Smirnov test is as follows you obtain the sig and K-S where: significance If the significance (here Sig. of a test is higher than 0.05 the is normally distributed, if not implemented that has been assumed was not statistically normal. The results of the normality test are presented in Table 6.

The p-value is the same for Asymp product quality. Sig (2-tailed) is greater than 0.05 that is 0.078 as shown in SPSS output table. As shown based on the results of the normality test with Kolmogorov-Smirnov presented above, the data is normally distributed.

Table 6
Normality test

N	Asymp. Sig
27	0,078

Homogeneity Test

Homogeneity is then verified on normal distribution. The Fisher test provides a homogeneity test. The outcome of the data homogenous test calculation was presented in the attachment. If F(calculated) is smaller than F(table), then H0 is accepted, indicating that the data variance is homogeneous; if F(calculated) is greater than F(table), then H0 is rejected. The criterion of homogeneity employed to test the homogeneity of the data. Here are the outcome of the homogeneity testing of pretest and posttest:

Table 7
Results of homogenity test

Statistics	Pretest		Posttest	
	Experiment	Control	Experiment	Control
Fcal	3,46		3,61	
Table	4,23		4,23	
Conclusion	Homogeneous		Homogeneous	

Table 7 above shows the homogeneity test scores for pretest and posttest in the experimental and control classes. Fcal value for the pretest of experimental versus control group was 3.46, whereas the posttest Fcal of the experimental versus control was 3.61. As

it was observed that Fcal < Ftabel for all data from both classes we claim that the samples have equal variance and are homogeneus.

Hypothesis Test (t-Test)

The necessary test of data analysis was performed to think that the test results data of all the classes is homogeneous as well as uniform distribution with a period. Then data analysis is proceeded to the second step, namely, hypothesis testing, to decide if the influence exists or not. This hypothesis is analysed with t-test, as it follows: the Ho is accepted if the t count > t table as well as, it is rejected if t count < t table. The hypothesis test results for the experimental and control classes are presented in Table 8.

Table 8
Results of hypothesis test

T	Sig.
1.569	0.000

Table 8 indicates the hypothesis testing result, which is the value of test tcal > ttable = (1.569 > 0.684). So Ho is rejected, it states that the use of the PjBL model integrated with STEAM has a significant influence on student learning outcomes.

Coefficient of Determination (R^2)

The coefficient of determination, R^2, indicates the extent to which the independent variable (X) explains the variance in the dependent variable (Y). It represents the percentage of variance in Y that can be attributed to X. Thus, R^2 is useful for both making predictions and assessing the individual and combined effects of X on Y.

Table 9
Coefficient of determination

R	R Square	Adjusted R Square	Std. Error of the Estimate
.315	.291	.288	2.251

We know from above SPSS output Table 9 that the r square value is 0.291 and the r coefficient or determination r is 0.315. The value of coefficient of determination (R) include 31.5%. This diagram explains that partially there is the effect of learning model of integrated STEAM PjBL by 31.5% of the learning outcome of the fifth grader student's at Bareng 3 State Elementary School. In the meantime, the remainder of the variables (either not present in the regression equation or not modeled) have an impact on the other 100% - 31.5% = 68.5%.

Effect Size

The effect sizes are reported for the measurements in this study. There is also an effect size that allows us to estimate how one of our variables is predicting another variable. The effectiveness of the PjBL learning model with STEAM integration on student learning processes and outcomes can be determined by conducting testing with the effect size test. The effect size calculation in the present study yielded the following results, as presented in Table 10.

From the findings derived from these calculations, it is known that there is an impact on student learning outcomes that

Table 10
Effect size results

Class	N Gain	SD	Effect Size	Category
Experiment	82,0577	25,0011	0,3	Keep
Control	70,2905	22,9901		

can be cultivated by applying STEAM-integrated PjBL learning models. The number 0.3 listed in the table means that the contribution of such PjBL teaching material has weak but to a moderate influence on student learning outcome.

DISCUSSION

Recent studies have suggested that integrating STEAM into the Project-Base Learning (PBL) approach could enhance students' learning. It can also be used to develop critical thinking skills, collaboration, communication patterns, and student creativity in supporting the development of 21st century skills. The research in SDN Bareng and SDN Dadaprejo 2 has also showed that an approach of PjBL exercises at a PDISB can drive students to study curriculum material with interest, build the character, and drive student seriousness in the process of learning and teaching in schools. (Mardhatillah et al., 2019).

According to (Sari & Prasetyo, 2021) Based on the PjBL model, it may offer students the chance to learn actively and autonomously. This can improve critical thinking skills in students. The results or findings of this study are consistent with this statement by proving that the PjBL model integrated with STEAM can significantly improve the learning outcomes of students indicated by the improvement of the average score of 48.52 (before the treatment) to 82.05 (after the treatment) in the experimental group. HOT skills have a correlation with the enhancement of learning achievements based on (Chamisijatin et al., 2023). Research shows that students involved in project-based learning have complex problem-solving abilities. Furthermore, the integration of STEAM in project-based learning has been shown to positively influence various aspects of student disposition and knowledge, including attitude, confidence, and overall understanding of STEAM concepts (An, 2020).

This research shows that students' abilities have improved with the use of integrated STEAM PjBL to improve learning outcomes and 21st century skills. The research showed that the increase in student learning outcomes increased from 48.02 and increased to 82.05 after the implementation of PjBL integrated STEAM. This is in line with the results of previous relevant research. The results of the study showed that PjBL's integrated STEAM learning had an impact on improving students' skills in the components of science literacy, statistics, and students' ability to think critically. These results are also supported by student responses with improved learning outcomes and activities that become better (Oanh & Dang, 2025; Winarni et al., 2024)

Based on this context, research on the application of STEAM provides additional

diction in improving 21st century skills, especially in the focus of creative thinking skills and collaboration. (Rati et al., 2023) also stated that HOTS (Higher Order Thinking Skills) based teaching materials can improve student learning outcomes. The material is believed to be able to support the learning process with a project-based learning approach that focuses on developing high-level thinking skills in elementary school students (Hamzah et al., 2022; Purwati et al., 2024). Furthermore, project-based learning has been shown to improve overall student learning outcomes and scientific abilities by providing practical, hands-on experience, leading to more meaningful learning (Fitriani et al., 2023).

This approach enables students to develop essential problem-solving abilities and fosters engagement in authentic learning processes (An, 2020). This aligns with findings that emphasise the importance of active, inquiry-based learning environments for developing 21st-century skills such as critical thinking, creativity, and problem-solving (Huijser et al., 2015; Komala et al., 2020). This pedagogical framework, when implemented effectively, fosters a deeper understanding of scientific and mathematical concepts by integrating them with technological, engineering, and artistic elements (An, 2020; Chistyakov et al., 2023). Specifically, this integrated approach encourages students to engage in collaborative problem-solving, thereby enhancing their higher-order thinking skills and fostering a holistic understanding of complex subjects (Lu et al., 2021). This method allows students to develop practical skills that would otherwise be difficult to acquire, preparing them for real-world challenges (Jos Akkermans, 2018). This aligns with research demonstrating that project-based learning enhances cognitive and psychomotor skills, enabling students to apply knowledge in practical contexts and fostering critical thinking (Fitriani et al., 2023).

Based on various theories, the results of this study are considered relevant and in line with the theory of constructivism developed by Piaget. The research revealed that students can learn actively through exploration and interaction with their environment. The process of applying STEAM integrated with PjBL, Students will be active in the learning process and will not depend on information obtained passively so that students are directly and actively involved in the learning process. This allows students to build new understandings based on direct learning experiences. The process also has a link to Vygotsky's scaffolding theory, which emphasises that the teacher acts as a facilitator who provides temporary guidance. Students can gradually take control in learning independently. This aligns with the constructivist view that knowledge is actively constructed by learners through their engagement with the environment and collaboration with peers and instructors (Huijser et al., 2015). The PjBL model, particularly when integrated with STEAM, facilitates a learner-centred approach where students conduct research, synthesise theory and practice, and apply knowledge

to real-world scenarios (An, 2020). This pedagogical approach also aligns with Dewey's emphasis on experiential learning, where students learn by doing and reflecting on their experiences, thereby developing a deeper understanding of disciplinary content and strategic skills (Lu et al., 2021). This active engagement fosters a more profound understanding and retention of knowledge, contrasting with passive learning methods.

Moreover, the collaborative nature inherent in STEAM-integrated PjBL models, where students work in groups to solve challenging, open-ended problems, cultivates essential teamwork and communication skills (Jos Akkermans, 2018). This aligns with the notion that learning is an active, constructive process within a unique contextual environment, necessitating deeper awareness and ownership of ideas through collaborative engagement with practical problems (Schechter, 2011). Such approaches encourage students to explore and plan to learn activities, fostering curiosity and problem-solving abilities crucial for navigating complex real-world phenomena (Adriyawati et al., 2020; Lu et al., 2021). Furthermore, this framework encourages students to generate questions and actively participate in projects, thereby fostering a sense of ownership over their learning and promoting deeper engagement with the subject matter (Hidayat et al., 2024). This constructivist pedagogical approach, exemplified by Project-Based Learning, posits that knowledge is not passively received but actively constructed by learners through engagement with meaningful experiences and social interaction (Al-Kamzari & Alias, 2025; Boakye-Yiadom et al., 2024). Consequently, this paradigm emphasises student autonomy and the development of higher-order thinking skills through authentic problem-solving scenarios, rather than rote memorisation (Jensen et al., 2021). This further aligns with the concept of constructionism, where learners create tangible artifacts to demonstrate their understanding, thereby organising their learning and enhancing engagement (Balslev & Andersson, 2020). This pedagogical approach, by integrating problem-based learning and project-based learning with STEM and arts, promotes self-directed learning and fosters essential problem-solving skills, which are crucial for addressing complex, real-world issues (Schechter, 2011). This integrated approach is particularly effective in cultivating 21st-century skills, such as critical thinking, creativity, and collaboration, which are essential for navigating an increasingly complex global landscape (Mutanga, 2024; Velmurugan et al., 2023). Indeed, such pedagogical styles have been demonstrated to significantly enhance content knowledge retention, improve problem-solving capabilities, and strengthen critical thinking skills among learners (Mokoka et al., 2023). These approaches also boost self-efficacy and engagement in STEM subjects, concurrently increasing interest in pursuing STEM-related careers (Holgaard et al., 2023). This transformation from traditional pedagogical methods to constructivist frameworks like project-based learning and

flipped classrooms represents a significant shift towards student-centred learning that contextualises educational information and fosters solution development as a primary means of demonstrating understanding (Haase et al., 2023). This model challenges students to go beyond mere memorisation, fostering a deeper, more enduring comprehension of subjects (Mutanga, 2024). This shift towards active, experiential learning environments also significantly enhances learner self-efficacy and promotes a greater interest in STEM fields, directly addressing the need for a skilled future workforce (Geil et al., 2023; Napoleone et al., 2023; Otto et al., 2023). Moreover, these contemporary pedagogical strategies, including the integration of constructivist principles with technology, are crucial for preparing students for the challenges of the digital age by cultivating adaptable skills, interdisciplinary thinking, and lifelong learning habits (N, 2024). These approaches empower students to become proactive learners, capable of navigating complex information, and contributing innovative solutions to societal challenges (An, 2020; Otto et al., 2023). This includes developing robust teacher professional development programmes that equip educators with the necessary skills to integrate new technologies and foster a productive disposition in students, thereby empowering connected learners in a connected world (An, 2020). This paradigm shift necessitates a relational and transformative model of learning, moving beyond traditional academic skills to integrate essential learning dispositions, values, and attitudes necessary for the emerging networked society (Huijser et al., 2015).

This comprehensive framework emphasises the critical need for educational systems to evolve, incorporating strategies like inquiry-based learning and collaborative problem-solving to cultivate essential 21st-century skills (Adeoye et al., 2024). Such innovative pedagogies, including Project-based Learning and flipped classrooms, have demonstrated significant growth in student outcomes across mathematics and science courses compared to traditional instructional methods (Mokoka et al., 2023). Furthermore, project-based learning has been shown to improve student attitudes towards mathematics and enhance collaborative skills, while the flipped learning approach has garnered significant interest for its potential to engage both educators and students in the teaching and learning process (Rehman et al., 2024; Santhanasamy, 2022).

This study produces findings that show that learning outcomes with the STEAM-integrated PjBL model have improved well. The PjBL approach is not only relevant in the context of 21st century learning but also effective for improving student academic outcomes and achievements at various levels of formal education. Therefore, the integration of the PjBL model with STEAM can be considered as one of the innovative learning strategies to answer the challenges of education in the current and future digital era.

CONCLUSION

This study concludes that the STEAM-integrated Project-Based Learning (PjBL STEAM) model is considered effective for improving student learning outcomes in elementary schools. This study, which took the object of two elementary schools in Indonesia, was applied using the Quasi Experimental Design method and had good implementation results. The results showed that the application of the PjBL STEAM model could increase the average score of student learning outcomes from 48.52 to 82.05 in the experimental group. In addition, this STEAM PjBL model also contributes to the development of 21st century student skills, namely critical thinking, collaboration, and communication. The results of this study can be applied and extended to studies in other schools with the integration of PjBL and STEAM models and methods that can improve learning outcomes and foster students' higher order thinking skills among elementary schools.

This research has conducted hypothesis testing, effect size analysis, and the coefficient of determination. The test results concluded that the STEAM PjBL model has a moderate level of impact on improving student learning outcomes in elementary schools. The effectiveness of the PjBL model in this study increased by 31.5%. These results highlight the importance of implementing innovative learning models integrated with 21st century skills in education in primary schools. It aims to provide students with knowledge to better face global challenges in the future.

This research has implications for education in Indonesia and several countries that have pluralistic characteristics such as Indonesia. The concrete implications of research in elementary school learning are the implementation of models in various learning materials. PjBL's integrated STEAM learning can improve students' understanding of concepts and high-level thinking skills. Research can also be an evidence-based policy for the government in encouraging the implementation of innovative learning that is in line with the curriculum in Indonesia. This has the opportunity to improve students' ability to think critically and be relevant to the skills needed in the 21st century global workplace.

In general, this research may have limitations. The samples used are still on a narrow scale. Future research is expected to examine or examine more deeply the impact of PjBL STEAM in elementary schools and its influence in improving critical thinking, collaboration, and communication skills in students. Future research is also expected to have more diverse subject and object characteristics to justify specific educational problems and needs.

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Final Project Guidance Patterns in Graduate Schools: Students and Lecturers Perspectives

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ABSTRACT

The Director General of Indonesian Higher Education regulates the completion of postgraduate course final assignments in four semesters (thesis) and six semesters (dissertation). Final assignment guidance is followed by students starting from the second semester of study with the lecturer according to the faculty's decision. The pattern of final assignment supervision influences student graduation success. The aim of this research is to explore the experiences of students and lecturers in the process of completing final assignments. The research method uses a qualitative approach with the Narrative Inquiry method. The data collection technique used in-depth interviews was conducted with 7 students who were completing their final assignments and 3 postgraduate lecturers. The data analysis technique uses qualitative content analysis. Multidisciplinary theory is used to contextualise research findings. The main finding of this research is the need for a multidisciplinary-based guidance pattern to accommodate the acceleration of completing students' final assignments. Furthermore, the results of this research explain how students experience taking part in final assignment supervision with their supervisor. The research findings also show that students and lecturers believe that multidisciplinary patterns have the potential to be implemented with promising success. This study found that the multidisciplinary pattern in final assignment supervision is most important for students to use when determining research titles, research reference sources, selecting supervisors, and scheduling final assignment guidance.

Keywords: Final project, graduate schools, postgraduate

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INTRODUCTION

Completing a final project at a high level is not only an academic issue, but also closely related to students' readiness to face psychological, social, and institutional pressures (Cole et al., 2004; Cordeiro et al., 2022; Lowe & Cook, 2003). Various studies have shown that students are susceptible to academic and emotional burnout during the mentoring process, particularly during the thesis or dissertation writing stage (Sverdlik et al., 2018). Therefore, the mentoring pattern implemented by the supervisor significantly contributes to students' success in completing their studies on time (Bagaka's et al., 2015; Jacobi, 1991; Rodger & Tremblay, 2003). Therefore, exploring effective mentoring patterns is crucial for improving the quality of continuing education (Andersen & West, 2020).

The reality of the climate in higher education in the last two years shows a trend that focuses more on developing students' research skills rather than professional or transferable skills regarding study completion and has been ongoing in higher education practice for many years (Guo et al., 2020; Viberg et al., 2018). Meanwhile, the condition of postgraduate students in higher education is easily stressed due to life changes, study pressures, and financial independence (He et al., 2023). This condition can be observed from the beginning when prospective postgraduate students face a dilemma in determining the university of their choice when registering for master's and doctoral programmes (Acharya et al., 2019). Experiences of life in college such as individual differences and demographic factors, as outlined above, may also inform and influence students' expectations of personal guidance in higher education (Yale, 2019).

Facing challenges in completing students' final assignments, a special support programme is needed that is appropriate to the students' conditions. Research results show structured coaching approaches can increase retention and degree completion (Blakeslee et al., 2022), while whole-class approaches to co-creation have the potential to engage students more than other approaches (Bovill, 2020), and genre-based approaches to guide students in writing final assignment introductions (Stapa et al., 2014). Social factors such as support systems have been found to play an important role in academic achievement in college (Mishra, 2020). Other research findings suggest family emotional support plays an important role in promoting positive academic outcomes (Roksa & Kinsley, 2019).

In addition to psychological factors, the dynamics of the relationship between students and their supervisors are also influenced by academic culture and institutional structures. In some Asian countries, strong hierarchical relationships between lecturers and students can hinder open communication, thus impacting the smooth running of the mentoring process (Lee, 2018). Conversely, in Western academic traditions, a collaborative approach is emphasised to encourage

students to develop research independence. This suggests that mentoring patterns are not universal and need to be tailored to the socio-cultural context and the student's academic needs.

Current scientific developments also demand a multidisciplinary approach in the preparation of final assignments. Students are no longer satisfied with mastering a single field of study; they are also required to be able to integrate various disciplines to address complex issues facing society (Jacobs & Frickel, 2009). In this context, mentoring patterns involving cross-disciplinary approaches are crucial for enriching students' perspectives in designing research and writing scientific papers. Thus, the implementation of a multidisciplinary mentoring pattern has the potential not only to accelerate study completion but also to improve the academic quality of graduates.

Higher education institutions and the academic community ensure graduation for students who are actively registered and carry out their studies to completion (Setiawan et al., 2024; Tight, 2020). Following international movements in recent decades, changes have been found in the way lectures are delivered in higher education, from traditional instructor-based teaching models to active, student-centred learning experiences (Murillo-Zamorano et al., 2019). Interaction with other people (for example, supervisors, theorists) in the context of preparing a final assignment can develop students' epistemology (Xu & Zhang, 2019). Social interactions with others writing in the same genre serve as opportunities to better understand these relationships (Mochizuki, 2019).

Parameters of student study success can be viewed from several domains. Study success includes successful completion of a first degree in higher education to the greatest extent, and successful completion of individual study assignments to the smallest extent (Ifenthaler & Yau, 2020). The potential influence of data mining analytics on student learning processes and outcomes has been realized in higher education as a material for institutional development (Aldowah et al., 2019).

Furthermore, institutional support through regulations, resources, and monitoring systems is also a key factor in students' success in completing their final project. A study by Bitzer (2011) showed that the success of postgraduate programmes is largely determined by institutional policies that provide academic, administrative, and emotional support for students. Therefore, this study is relevant because it provides an empirical overview of the experiences of students and supervisors in navigating the multidisciplinary final project guidance process, as well as how this pattern can be optimised in the context of higher education in Indonesia

METHODOLOGY

Participants

The qualitative observational study in this research was carried out through in-depth interviews with 7 students (3 Masters/ master's and 4 Doctorates/Doctorates) and 3 postgraduate lecturers as supervisors at

one of the state universities in East Java. The inclusion criteria for participants in this study were as follows: (a) having an academic diagnosis recommended by a postgraduate lecturer, (b) being currently in their early, middle, or final semesters, (c) residing in Malang, Indonesia, and (d) possessing the ability to read, comprehend, and write a final assignment. Additionally, all research communications were conducted in Indonesian. This research received approval from the Postgraduate Director of the State University of Malang (05/2023) and all interview participants filled in their identification and agreed after the research objectives were explained to them. There is no fixed sample size, and interviews are conducted until saturation of interview topics is reached, namely a multidisciplinary-based final assignment (thesis/dissertation) guidance pattern. All in-depth interview results were read repeatedly until they found "threads" in the term of narrative inquiry as a replacement for the word "theme" in the interview results.

Instruments

The final project performance scale can be seen in Table 1.

Table 1
Multidisciplinary based final project (thesis/dissertation) guidance service performance scale

Aspect	Indicator	Score			
		1	2	3	4
Man	I master passive English				
	I have limitations in finding references to compose my final assignment	□	□	□	□
	My motivation to complete my final assignment changed	□	□	□	□
	I carefully read every part of the final assignment before submitting it to my supervisor	□	□	□	□
	The supervisor observes the student's strengths during the process of preparing the final assignment (thesis/ dissertation)	□	□	□	□
	The supervisor observes the student's progress and success during the process of preparing the final assignment (thesis/ dissertation)	□	□	□	□
	The supervisor observes the student's progress and success, and conveys appreciation (reward) for the performance in preparing the final assignment (thesis/dissertation) to increase the student's self-efficacy	□	□	□	□
	The supervisor motivates students to take immediate action (revise, read references, etc.).	□	□	□	□
Material	I don't understand the procedure for writing a final assignment	□	□	□	□
	I experienced difficulties in collecting research data	□	□	□	□
	The tuition fees are born independently by me	□	□	□	□

Table 1 *(continued)*

Aspect	Indicator	Score			
		1	2	3	4
	I read and consistently follow the Guidelines for Writing Scientific Papers (PPKI) and the General Guidelines for Indonesian Spelling (PUEBI).	□	□	□	□
	I read the latest theories, scientific journals and research methods and use relevant primary sources that support the completeness of research data	□	□	□	□
	I create a realistic plan that is approved by all supervisors, and consistently carry it out	□	□	□	□
Method	My research methodology is weak	□	□	□	□
	My research analysis is weak	□	□	□	□
	I consult with all supervisors intensively, both regularly and incidentally, including when preparing the methodology	□	□	□	□
	Supervisors serve student consultations wholeheartedly	□	□	□	□
Machine	I can carry out data analysis independently	□	□	□	□
	The requirements for my final project proposal are incomplete	□	□	□	□
	I went through two activities together, namely working while compiling the final assignment	□	□	□	□
	I maintain the quality of both technical and substantive conceptual aspects of research	□	□	□	□
	I continuously document the guidance process for preparing my final project (Thesis/Dissertation) in the guidance recording format that has been provided	□	□	□	□
	I am more independent and prioritise completing the preparation of my final project (Thesis/Dissertation) rather than other tasks/activities	□	□	□	□

The performance scale presented in Table 1 serves as a self-evaluation instrument to assess students' progress and readiness in completing their final projects across the four identified parameters. Following this assessment, in-depth interviews were conducted with the students using a structured interview rubric, which is detailed in Table 2.

Table 2 shows a list of interviews aimed at postgraduate students. Meanwhile, the interview rubric for lecturers selected as final assignment supervisors based on postgraduate recommendations can be seen in Table 3.

Table 3 is a list of questions for supervisors who are assigned to accompany the completion of graduate students' final assignments. This interview rubric is open because informants can convey real information. This qualitative approach aims not only to focus on one aspect of information at one time, but to allow the story to flow and develop to produce in-depth exploration. Posterior inductive analysis was used to determine main themes,

Table 2
List of interview questions for students

No	Question
1	Please tell us about your experience in general, about the guidance you have experienced (about feelings, relationships with the supervisor, institutional support, guidance guidelines, smoothness, expectations, etc.)!
2	Please tell us about how you plan to complete your thesis/dissertation in the Basic Education Postgraduate Programme!
3	Please tell us what difficulties you experienced while completing your thesis/dissertation in the Basic Education Postgraduate Programme!
4	How does your supervisor provide services regarding completing your thesis/dissertation in the Basic Education Postgraduate Programme?
5	Does your supervisor have a special approach to support the completion of your thesis/dissertation? Please explain it to us.
6	What do you think about the guidance pattern from supervisors who practice this pattern in the process of completing your thesis/dissertation?
7	Tell us about your obstacles/difficulties when following the guidance pattern implemented by your supervisor? Please explain your argument regarding this to us!
8	Tell us your opinion or suggestion regarding the guidance pattern for completing a thesis/dissertation so that it is completed/graduated on time in the Basic Education Postgraduate Programme?
9	Tell us your opinion or suggestion regarding guidance with a multidisciplinary approach in the thesis/dissertation completion process?

Table 3
List of interview questions for lecturers

No	Question
1	Please tell us about your experiences in general, regarding the guidance you have experienced/carried out to students (about feelings, relationships with students, institutional support, guidance guidelines, smooth running, hopes, etc.)
2	Please tell us about how you plan to supervise your thesis/dissertation in the Postgraduate Programme, Basic Education Study Programme
3	Please tell us what difficulties you experienced during your thesis/dissertation supervision in the Postgraduate Programme, Basic Education Study Programme
4	How do students participate in guidance services for completing their thesis/dissertation in the Postgraduate Programme, Basic Education Study Programme?
5	Do you have a special pattern of approach for thesis/dissertation guidance? Please explain it to us.
6	What do you think about students' responses to the guidance pattern from you who practice this pattern in the process of completing a thesis/dissertation?
7	Tell me about your obstacles/difficulties when implementing this guidance pattern? Please explain it to us.
8	Tell us your opinion or suggestion regarding the guidance pattern for completing a thesis/dissertation so that it is completed/graduated on time in the Postgraduate Programme, Basic Education Study Programme.
9	Tell me your opinion or suggestion regarding guidance with a multidisciplinary approach in the thesis/dissertation completion process?

Table 4
Thematic analysis phase

Thematic Analysis Phase	Description
Phase I	Familiarisation with the data: transcriptions of all interviews were revised for corrections (472 ± 1398 words per interview, mean ± standard deviation).
Phase II	Generating initial codes: a list of 7 codes was generated (e.g. general experience, planning for completing the final project, difficulties, opinions about the supervisor, opinions about the supervisor's pattern, difficulties following the supervisor's pattern, suggestions for the best mentoring pattern, comments about the multidisciplinary approach).
Phase III	Theme search: revision and analysis of interrelated text segments and codes resulted in a first draft of 4 themes (e.g., general experiences, study planning, experiences with supervisors, and diagnosis of a multidisciplinary approach).
Phase IV	Reviewing themes: literacy posterior review of themes and text segments led to a reduction in the number of themes from 7 to 4.
Phase V	Defining and naming themes: the "define and refine" approach described by Braun and Clarke (2006) led to the suggestion and definition of two main themes for analysis, as explained in the Results section below.
Phase VI	Report generation: results as described in the Results and Discussion section below correspond to this phase.

subthemes, relationships between them, and perceptions of temporal changes. A single meeting per participant was conducted, ranging in duration from 50 minutes to 1 hour 50 minutes. Participants answered questions freely in their own words, and follow-up questions were used to clarify unclear descriptions. Interviews were conducted in Indonesian and Javanese.

Data analysis uses thematic analysis techniques following Braun and Clarke's guidelines (Braun & Clarke, 2006), The thematic analysis technique is carried out in six phases of an iterative process which aims to identify and analyse patterns (themes) in the qualitative data collection resulting from in-depth interviews between researchers and interview participants until consensus is reached (Lupón et al., 2023). The thematic analysis phase is seen in Table 4.

Table 4 shows the thematic analysis phases based on Braun and Clarke's guidelines (Braun & Clarke, 2006). Thematic analysis produces qualitative data as research findings. The analysis, hierarchy of interview themes, and final categories of data were discussed among the authors, and the results were decided upon by consensus.

Procedures

Interview participants were contacted via WhatsApp social media messages to arrange the date, time, and location of each interview, a method chosen for its practicality and accessibility in maintaining communication with postgraduate students who often had busy schedules and resided in diverse regions. All interviews were conducted over a four-month period,

from May 2023 to August 2023, allowing the researchers sufficient time to build rapport with participants and to collect data systematically. During the interview process, data were recorded in handwritten notes using structured interview sheets to ensure that no key information was overlooked and to maintain consistency across respondents. The meetings with interview participants were carefully organised into two sequential parts. First, participants were informed about the overall purpose of the research, including its aims and potential benefits, and were then asked to provide sociodemographic information such as name, gender, study programme, semester level, home address, and contact details (cellphone number/ email). In addition, they were required to submit details of their academic context, including the research title, the name of their supervisor, the duration of their supervision experience, and the status of their final assignment (whether ongoing or completed).

Second, after the demographic and contextual data collection, participants were directed to complete a multidisciplinary-based final project performance scale designed to evaluate their progress in preparing a thesis or dissertation. This instrument consisted of 25 statement items grouped into four key parameters man, material, method, and machine—each representing different aspects of postgraduate academic performance. The "man" parameter assessed personal factors such as motivation, perseverance, and communication skills; "material" evaluated the availability and quality of references, data, and resources used in the research; "method" measured the level of understanding and application of appropriate research methodologies; and "machine" examined the use of technological tools and digital platforms in supporting research activities. By incorporating these four parameters, the instrument provided a holistic framework for understanding the students' competencies and challenges in completing their final assignments. This structured approach not only ensured that the interviews generated rich and comparable data but also allowed the research team to capture the complex interplay between personal, academic, and institutional factors influencing postgraduate study completion.

RESULTS

10 interview participants with inclusion characteristics were interviewed, were in the first, middle and final semesters, and lived in Malang City. Interviews lasted between 50 minutes and 1 hour 50 minutes. Interview analysis determined 4 main themes from 7 themes that had been accumulated in the third phase of thematic analysis. The common thread that underlies and connects these 4 main themes is (1) general experience, (2) study planning, (3) experience with supervisors, and (4) diagnosis of a multidisciplinary approach. The common thread that connects the 4 main themes is time management and discipline towards commitment.

Theme 1 Result: General Experience

Collectively, it is evident from interviews to what extent the experience of Postgraduate Basic Education students is in the process of completing their final assignments. Several students described the general experience that they felt was fun and full of challenges.

> ***A** As an alumnus of the UM Postgraduate School Doctoral Programme, I feel that in the mentoring process, I really enjoyed, enjoyed, and was challenged because I got a lot of useful knowledge from very professional supervisors (E/Pps/2023)*

> *It takes more patience to contact lecturers. When you get the answer, it's a little bit small. But when he came back, there was more. (RZ/Pps/2023)*

> *In general, when I decided on the title, I changed it two or three times. I had difficulty finding sources and methods; supervisor 1 was more supportive, while supervisor 2 changed many variables and did not provide specific references. And I ended up dominantly following my mentor. (SB/Pps/2023.*

Postgraduate students believe that the journey to complete their final assignment involves various challenges according to their individual circumstances and conditions, both between student and lecturer. A change in research direction was also felt by some students due to differences in research orientation between the students' desires and the research roadmap that supervisors at the Postgraduate School had.

Theme 2 Result: Study Planning

Collectively, it is evident from interviews to what extent the Basic Education Postgraduate students' study planning is in the process of completing their final assignments. Some interview results that illustrate this evidence include:

> *At the beginning of college, I made a list of activities between lectures. Over time, this thesis fell apart due to my own fault due to the PPG schedule, because the PPG schedule had really changed. (SB/Pps/2023)*

> *Supervisors are chosen by students collecting plans and post-determining according to supervisor research umbrellas. And coincidentally, my choice was in accordance with what was granted (RZ/Pps/2023). Planning for preparing a dissertation begins with:*

a. After the supervisor decree was issued, I tried to find the contact numbers of the supervisors and tried to make contact and introduce myself. Tell me who I am, from which agency and convey the dissertation topic plan that will be worked on
b. Receive input and suggestions directed by the supervisor.
c. Immediately look for reference material that can support writing your dissertation.

d. Make progress and quote one day "one-three paragraphs".
e. Consultation with supervisors (target once a week but still respecting the supervisors' busy lives)
f. Manage daily schedules and balance of work and dissertation completion (E/Pps/2023).

Study planning starts from the beginning when postgraduate students programme courses and research plans in the first semester. The research proposal is then reaffirmed in the second semester when students take the research proposal development course for the Masters/master's level and the third semester for the Doctoral/Doctoral level. Determination of research topics and themes is decided based on the results of the Postgraduate mapping which is known to the supervisor and students.

Theme 3 Result: Experience with Mentor

Collectively, it is evident from interviews to what extent the Postgraduate Basic Education students' experience with supervisors in the process of completing their final assignments. Some interview results that illustrate this evidence include:

> *My supervisor provides a good academic atmosphere. We are taught to develop Curiosity. My supervisor has also given me enough time to complete my dissertation. He always monitors the progress of my dissertation from time to time and hopes that I will graduate on time. (E/Pps/2023)*

> *Most of the students' close friends are elementary school teachers, almost from the same class. The relationship with the lecturer is quite familiar; there are some boundaries that need to be maintained. Frequently contact me first every day, last 1 day (RZ/Pps/2023).*

The mentoring activities experienced by students and supervisors fall into a two-way interaction pattern. Students adapt to maintain communication with their respective supervisors. Even though it is found that there are several mentoring processes that run smoothly, there are several different situations experienced by other students when they undergo mentoring activities due to the position of the supervisor and the busyness of their respective roles (between students and lecturers) because most postgraduate students work as teachers. and Lecturer.

Theme 4 Result: Multidisciplinary Approach Diagnosis

Collectively, it is evident from interviews to what extent the diagnosis of a multidisciplinary approach is given to postgraduate students in basic education in the process of completing their final assignments. Some interview results that illustrate this evidence include:

> *I really agree with the consideration of a multidisciplinary approach in completing this dissertation, because I am sure that this approach will be able to encourage students to quickly complete their studies, especially*

in preparing their dissertation. It is believed that this approach will be able to solve complex problems encountered by students. This approach provides a different perspective to create broader possibilities in creating a series of questions in research and developing possible solutions to the problem (E/Pps/2023)

Multidisciplinary potential is carried out not only in the process, but from the dosbing selection period according to the plans of the researchers and lecturers (RZ/Pps/2023).

The perspective of a multidisciplinary approach understood by the informant is an academic system in supervision that allows for more varied interactions in scientific fields between students and supervisors to reach agreement on research proposals and research results at the end of the education programme at the postgraduate school. This knowledge is an initial indication for researchers that a multidisciplinary approach can potentially be applied in the education system at postgraduate schools.

DISCUSSION

The aim of this research is to explore the experiences of students and lecturers regarding a multidisciplinary approach in the final assignment completion process according to the students' and lecturers' views. The results of in-depth interviews that have been collected are then read repeatedly by the researcher until they find meaning according to the information conveyed by the informant and in accordance with the research objectives.

Results Theme 1: General Experience

Postgraduate students at the State University of Malang (UM) come from various regions in East Java, and some live at addresses according to their identities outside the East Java region. The inherent cognitive complexity of postgraduate students, to the assumption that critical thinking does not exist due to cultural background (Lin et al., 2023), to the diversity in the presentation of critical thinking, causes variations in the uniqueness of postgraduate students in participating in study completion activities in higher education.

In line with this, the interview results show that students' experiences in completing final assignments are coloured by a combination of enjoyment, challenge, and tension in navigating the mentoring process. Some students expressed appreciation for professional supervisors who provided knowledge and direction, while others highlighted the difficulty of accessing lecturers, inconsistencies in guidance, and frequent changes in research focus. These findings confirm that postgraduate mentoring is not only an academic process but also involves emotional resilience, adaptability, and negotiation between student expectations and supervisor standards (Hemer, 2012; Wisker, 2012).

Moreover, the experience of changing research titles and directions, as shared by several respondents, illustrates the dynamic

interaction between the individual's academic interests and the institutional research roadmap of the postgraduate school. Such misalignments can generate frustration but also foster growth in academic perseverance and critical engagement with scientific inquiry. Previous studies have noted that supervision often reflects power asymmetries and different epistemological perspectives, which shape how postgraduate students negotiate their research identities (Lee, 2008; Manathunga, 2007). Therefore, postgraduate guidance at UM demonstrates a dual nature: on one hand, it provides opportunities for intellectual enrichment and skills development, while on the other, it poses challenges of adjustment and alignment with supervisors' expectations.

This aligns with the perspective that postgraduate education is inherently situated within a social and cultural context where learning is co-constructed through dialogue, negotiation, and feedback cycles (Carter & Kumar, 2017). Students' reflections on their mentoring journey highlight the importance of building trust, consistency, and clarity of guidance from supervisors. At the same time, students are required to exercise self-regulation, persistence, and critical thinking to manage the complexities of supervision. Thus, the experiences at UM's Postgraduate School underscore the significance of adopting mentoring models that balance academic rigor with empathetic support, ensuring that students are not only guided towards successful thesis completion but also empowered as independent researchers in their respective fields.

Results Theme 2: Study Planning

One of the superior master's qualifications includes assignments involving the preparation of final assignments (Nozal et al., 2013). Programming for postgraduate students' study completion plans is carried out online via the website provided by the higher education institution. The phenomenon of lack of basic education in specialty profiles and doubts about professional development at the second stage (Baranova, et al., 2020). Postgraduate students' study orientations such as acquiring professional competence, struggling to manage various forms of communication, demanding task completion, and confusion of academic roles (Gjestvang et al., 2021). ultimately become references for completing Postgraduate studies.

The interview data reinforce these findings, showing that planning for thesis and dissertation completion is highly influenced by students' ability to manage time, balance professional duties such as PPG (teacher professional training), and adapt to the schedules and expectations of supervisors. For instance, some students admitted that although they had carefully planned their activities at the beginning, external demands disrupted their schedules, forcing them to reorganise priorities and strategies. This highlights the dynamic and fragile nature of study planning among postgraduate students, where professional commitments often intersect with academic responsibilities (Carter & Laurs, 2018).

Furthermore, planning is not merely an individual endeavour but also shaped by

institutional mechanisms, such as supervisor allocation and alignment with research roadmaps. The interviews revealed that students often adapt their study plans to the "research umbrella" of supervisors, underscoring the negotiation process between personal research interests and institutional directions. Such adjustments can foster flexibility but also create dependency, as students feel compelled to follow their supervisors' research orientations. At the same time, effective planning practices—such as proactively contacting supervisors, developing weekly writing targets, and maintaining consistent consultation—show that students who implement structured study plans are more likely to progress steadily. This finding resonates with earlier research emphasising the role of academic self-regulation and proactive communication in ensuring timely completion of postgraduate studies (Pyhältö et al., 2012).

Ultimately, the evidence from UM postgraduate students suggests that successful study planning requires a balance between external structures and internal discipline. While institutional policies, supervisor guidance, and workload distribution set the boundaries of planning, it is students' agency in organising time, setting achievable targets, and maintaining motivation that determines the sustainability of their study completion journey. Therefore, integrating formal academic planning platforms with personalised mentoring approaches can enhance postgraduate students' ability to adapt to shifting circumstances while maintaining long-term focus on their final assignments. This aligns with the perspective that postgraduate education must not only provide academic scaffolding but also develop students' metacognitive skills to manage the complexities of learning, working, and researching simultaneously (Guerin et al., 2015; Kumar & Stracke, 2007).

Results Theme 3: Experiences with Mentors

Postgraduate supervisors and students not only purely carry out their role as academics in higher education, but also actively participate in self-development programmes at higher education level. The available support programmes must not follow a universal approach but must consider the diversity of student profiles as the main basis for improving institutional quality (Cabral & Baptista, 2014).

The routines followed during the final assignment completion process do not always go according to plan at the beginning of the semester. Some of the obstacles experienced by postgraduate students include financial problems because financial assistance is an important modality in increasing success outcomes and reducing affordability concerns for students (Carales, 2020), and interpersonal communication problems that originate from personal conditions, social situations, and linguistic use of the mother tongue. excessive, and class culture (Chand, 2021).

At the same time, interviews revealed that the supervisory relationship plays a

crucial role in mediating these challenges. Students emphasised that supervisors who provide an encouraging academic atmosphere, stimulate curiosity, and consistently monitor progress contribute significantly to students' persistence and timely completion. This aligns with prior research noting that effective supervision fosters students' sense of belonging, confidence, and motivation, which in turn reduces attrition risk and enhances academic resilience (Hemer, 2012; Wisker, 2012).

Moreover, the social dimension of postgraduate life, such as relationships with peers and the nature of interaction with supervisors, also emerged as a vital factor. For example, students often find emotional support and academic reinforcement from peers with similar professional backgrounds, such as elementary school teachers in the case of basic education postgraduates. Meanwhile, the relationship with supervisors is described as both familiar and bounded, suggesting a balance between professional distance and personal accessibility. Research on postgraduate supervision has highlighted the significance of clear communication and negotiated boundaries in building trust and fostering academic independence while avoiding dependency (Lee, 2008; Manathunga, 2007). The students' reflections indicate that supervisors who are approachable and proactive in communication can mitigate feelings of isolation and sustain momentum throughout the thesis process.

In sum, postgraduate students' experiences demonstrate that completing final assignments is not only a matter of intellectual effort but also deeply embedded in financial, social, and supervisory dynamics. Supervisors who combine academic expertise with mentorship qualities are better positioned to help students navigate systemic and personal challenges. Therefore, postgraduate supervision should be understood as a holistic practice, integrating academic monitoring, relational support, and the cultivation of critical inquiry. Such an approach resonates with the broader framework of postgraduate education as a relational and cultural practice, where success depends on the interplay of institutional structures, supervisory practices, and students' agency (Carter & Kumar, 2017; Guerin et al., 2015).

Results Theme 4: Multidisciplinary Approach Diagnosis

The implementation of higher education in the postgraduate programme is oriented towards producing professional academic human resources based on the Tri Dharma of Higher Education. Guaranteeing the quality of postgraduate student education is very important in the higher education system, meanwhile the quality of course teaching is the key to guaranteeing the quality of talent development, as well as being a necessity for current career formation The urgency of the need for this multidisciplinary approach guidance pattern is also in accordance with the contents of points b, c and d of the Malang State University Chancellor's Regulation Number 16 of 2016 concerning Malang State University Education Standards which reads as follows

a. Point b: Students can organise interdisciplinary, multidisciplinary, or transdisciplinary research including theoretical studies and/or experiments.
b. Point c: Students can choose research that is appropriate, current, most advanced and provides benefit to humanity through an interdisciplinary, multidisciplinary, or transdisciplinary approach.
c. Point d: Students can develop a research roadmap with an interdisciplinary, multidisciplinary, or transdisciplinary approach.

These institutional standards highlight the recognition that postgraduate research cannot be confined to narrow disciplinary silos; instead, it must foster collaboration, innovation, and responsiveness to complex societal issues (Jacobs, 2014). The implication is clear: postgraduate programmes must design guidance patterns and supervisory practices that prepare students to navigate the demands of cross-disciplinary inquiry. This includes equipping them with the ability to synthesise theories, apply diverse methodologies, and communicate effectively across academic and professional communities. By institutionalising such approaches, higher education not only strengthens academic excellence but also enhances graduates' capacity to contribute meaningfully to solving real-world problems, from educational reform to technological innovation. Thus, the regulatory foundation and the urgency highlighted in recent scholarship both converge on the need for postgraduate education that is integrative, future-oriented, and globally relevant.

Referring to the discussion of research results, the multidisciplinary approach for students in completing their final assignment can be seen in the Figure 1.

Figure 1 illustrates the final project guidance pattern in a postgraduate programme with a multidisciplinary approach that emphasises collaboration between students, supervisors, and supervisors. The process begins with graduate students proposing research topics in accordance with issues stipulated in university regulations, encompassing the fields of science, technology, art, and community. These research proposals are then screened by the postgraduate faculty for acceptance or rejection. If accepted, master's students will be supervised by two supervisors, while doctoral students will be supervised by three supervisors. Subsequently, guidance is carried out through a mentoring contract with a four-component (4M) approach: man, material, method, and machine, each of which supports the development of a multidisciplinary scientific personality and the use of various research tools. This multidisciplinary guidance process consists of three main stages: an initial stage that emphasises the urgency of the research, research approaches, and scientific contributions; a middle stage that includes literature reviews, empirical studies, and research methods; and a final stage that emphasises the involvement of experts or field specialists, data analysis,

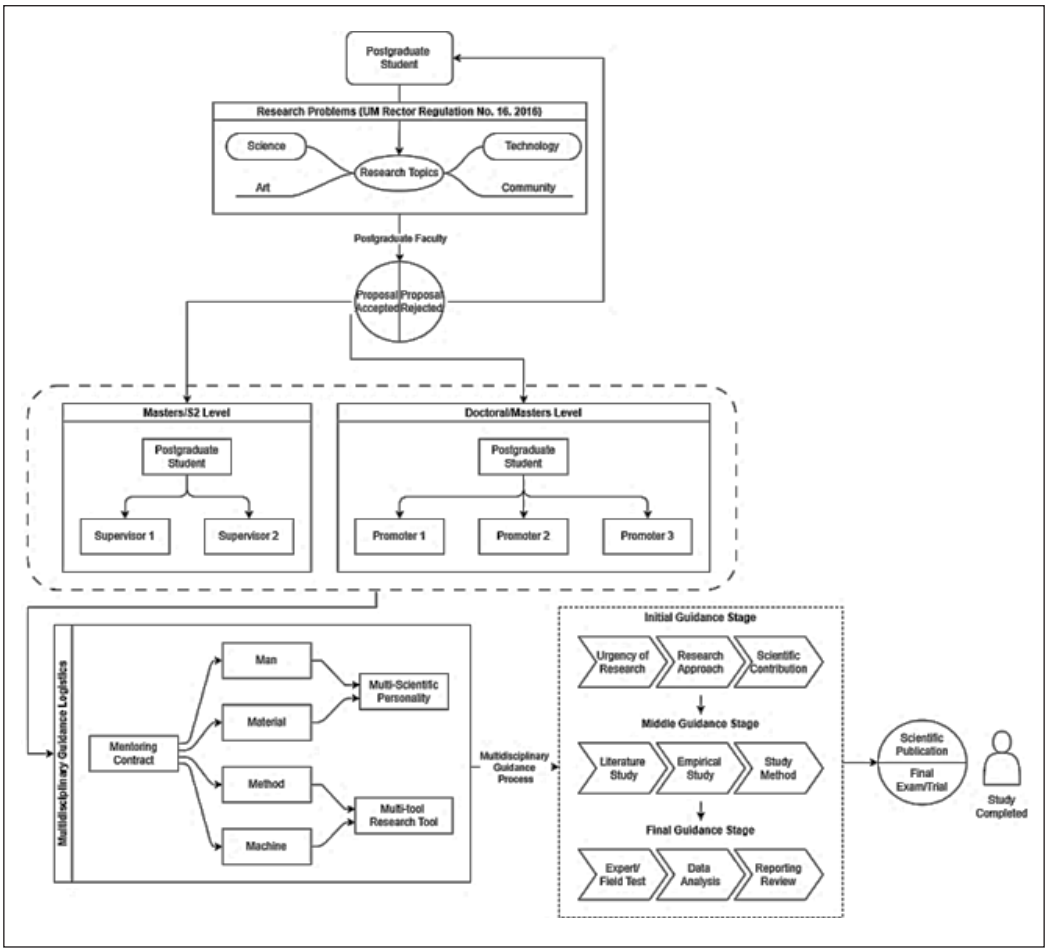

Figure 1. Postgraduate multidisciplinary approach final assignment guidance

and report review. All these stages culminate in scientific publications and a final exam, thus declaring students to have completed their studies with more holistic research competencies. Thus, this image shows the pattern of final project guidance in postgraduate studies as an integrative cycle that brings together the perspectives of students and lecturers in producing quality research that is relevant to academic demands and community needs.

CONCLUSION

This study highlights the critical role of a multidisciplinary guidance pattern in postgraduate education to accelerate study completion and mitigate student burnout. By integrating the 4M framework (man, material, method, and machine), this approach fosters a collaborative and supportive academic environment for both students and supervisors. Implementing this structured and flexible mentoring cycle enables postgraduate programs to better

accommodate diverse student needs while maintaining high standards of academic research and timely graduation.

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Children's Literature as Narrative Pedagogy in Indonesia

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ABSTRACT

The integration of children's literature in primary classrooms has been widely associated with creativity, critical thinking, and emotional development. However, limited research has systematically examined how narrative-based instruction fosters multidimensional student engagement within culturally contextualised settings. This study investigates how Indonesian primary school teachers strategically employ children's picture books to enhance behavioural, emotional, and cognitive engagement. Using a multiple case study design with an embedded mixed-methods approach, data were collected from classroom observations, document analysis, and Likert-scale questionnaires involving five purposively selected teachers and 116 students. The findings reveal that children's literature functions as a narrative-mediated pedagogical infrastructure that simultaneously supports active participation, emotional connection, and conceptual reasoning. Thematic analysis indicates that dialogic questioning, culturally relevant texts, and cross-disciplinary integration are key mechanisms for shaping engagement. While the study confirms the pedagogical value of story-based instruction, it also highlights the necessity of intentional scaffolding to prevent superficial engagement. The findings contribute to student engagement scholarship by illustrating how narrative structure functions as an integrative mechanism connecting behavioural, emotional, and cognitive dimensions.

Keywords: Children's literature, culturally responsive teaching, multiple case study, narrative pedagogy, primary education, student engagement

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INTRODUCTION

Contemporary primary education increasingly emphasises not only literacy acquisition but also the cultivation of multidimensional student engagement. In the context of 21st-century learning, classrooms are expected to foster active participation, emotional involvement, and higher-order thinking rather than passive knowledge transmission. However, in many primary settings, literacy instruction remains skill-oriented and text-bound, with limited pedagogical integration that connects reading activities to broader cognitive and affective development. This situation calls for pedagogical approaches that meaningfully integrate narrative experiences into classroom learning.

Children's literature offers significant potential in this regard, and children's picture books, in particular, may provide rich opportunities for imaginative and creative engagement through the interaction of narrative and visual representation (Ünal et al., 2024). Beyond serving as reading material, literary texts function as narrative spaces where learners negotiate meaning, identity, and values (Leland et al., 2023; Sever Serezli, 2024). Through storytelling, dialogue, and character exploration, children are invited to engage not only with textual content but also with moral dilemmas, cultural perspectives, and imaginative possibilities. In picture-book contexts, such engagement also involves interpreting visual elements and constructing meaning across verbal and visual modes (Trihastuti, 2023). Thus, children's literature may operate as a form of narrative pedagogy—an instructional approach that positions storytelling as a structured medium for learning.

Empirical studies have documented the cognitive benefits of literary engagement. Research indicates that children's literature promotes interpretive competence, inference-making, and critical thinking (Aisyah & Mustofa, 2023; Heyrani & Moghaddam, 2021). Literature-based language learning further enhances contextualised understanding and analytical reflection (Hossain, 2024). Narrative complexity encourages learners to analyse motivations, evaluate decisions, and construct alternative interpretations. These findings suggest that literary engagement contributes to cognitive depth beyond surface-level comprehension.

In addition to cognitive development, children's literature plays a crucial role in fostering emotional and social growth. Literary narratives facilitate empathy, perspective-taking, and emotional identification with characters (Heath et al., 2017; Torres, 2019). Emotional engagement refers to learners' affective responses such as enjoyment, interest, and a sense of belonging (Fredricks et al., 2004). Classroom practices such as reading aloud have been shown to strengthen children's positive attitudes toward reading and deepen their affective attachment to literacy experiences (Ledger & Merga, 2018). These studies indicate that literary engagement extends beyond comprehension to encompass emotional resonance and motivational orientation. Recent research on young learners' emotions

similarly highlights enjoyment and boredom as important dimensions of learners' affective experiences during classroom learning (Tsang & Davis, 2024).

Despite this growing body of research, much of the existing literature examines cognitive, emotional, or motivational outcomes in isolation. Few studies conceptualise literary pedagogy through an integrative engagement framework. The multidimensional model proposed by Fredricks et al. (2004), which distinguishes behavioural, emotional, and cognitive engagement, provides a comprehensive lens for examining how students participate, feel, and think within learning environments. However, empirical investigations rarely apply this framework to analyse how children's literature systematically fosters multidimensional engagement within classroom practice.

Within the Indonesian context, research has begun to explore teachers' efforts to integrate children's literature into literacy instruction (Durriyah et al., 2024). Nevertheless, these studies tend to focus on implementation challenges or general literacy outcomes rather than examining engagement processes holistically. There remains limited evidence on how structured narrative pedagogy simultaneously cultivates behavioural participation, emotional involvement, and cognitive depth among primary school learners.

Accordingly, this study seeks to address this gap by examining children's literature as narrative pedagogy in Indonesian primary education. By employing a case study design and analysing classroom practices through the multidimensional engagement framework, this research aims to provide an integrated understanding of how literary instruction fosters behavioural, emotional, and cognitive engagement in authentic classroom contexts. Specifically, this study addresses the following question: How does children's literature, when implemented as narrative pedagogy, foster behavioural, emotional, and cognitive engagement in Indonesian primary classrooms?

METHODOLOGY

Research Design

This study adopted a multiple case study design (Yin, 2018) to explore how children's literature functions as narrative pedagogy within authentic primary classroom contexts. Each participating teacher represented an individual case. The study aimed to identify recurring engagement patterns across cases while acknowledging contextual variations. Within each case, an embedded mixed-methods approach was employed. Qualitative classroom observations and document analysis constituted the primary sources of data, while quantitative questionnaire responses were incorporated as supportive triangulation. The design was qualitatively driven, as the primary objective was to generate interpretive insights into engagement processes rather than statistical generalisation.

Participants and Context

The study involved five Indonesian primary school teachers selected through purposive

sampling. The selection was guided by the intention to include information-rich cases capable of illustrating narrative-based pedagogical practices. The teachers met the following criteria: they had at least five years of teaching experience, regularly integrated children's picture books into classroom instruction, and were recognised by school administrators (based on documented involvement in literacy programmes and professional development activities).

These teachers incorporated children's literature not only in language lessons but also in subjects such as science, civic education, and health education. This cross-disciplinary integration provided an opportunity to examine literature beyond its conventional literacy function. A total of 116 students from Grades 3 to 5 participated in the study. Students were drawn from the respective classrooms of the participating teachers. The student participants represented diverse academic abilities and socio-cultural backgrounds, reflecting the natural heterogeneity of primary classrooms. Prior to data collection, institutional approval was obtained from school authorities. Parental consent and student assent were secured to ensure ethical compliance.

Data Collection

Data were gathered through classroom observations, instructional document analysis, and perception-based questionnaires administered to both teachers and students.

Classroom Observations

Non-participant classroom observations were conducted during lessons in which children's picture books were integrated into instructional activities. The observations focused on how teachers structured narrative-based instruction and how students responded behaviourally, emotionally, and cognitively. Field notes documented instructional strategies such as dialogic questioning, guided interpretation, collaborative tasks, and cross-curricular connections. Particular attention was paid to indicators aligned with engagement theory (Fredricks et al., 2004), including observable participation (behavioural), expressions of interest or emotional resonance (emotional), and evidence of analytical reasoning or problem-solving (cognitive).

Document Analysis

To complement observational data, lesson plans and selected instructional materials were analysed. This analysis aimed to examine how teachers aligned narrative content with learning objectives and whether engagement-oriented strategies were intentionally embedded within instructional planning.

Questionnaires

To support the qualitative findings, Likert-scale questionnaires were administered to teachers and students. Both instruments consisted of statements related to behavioural, emotional, and cognitive engagement dimensions, using a four-point response scale

ranging from Strongly Disagree to Strongly Agree. The student questionnaire was written in simplified language appropriate for primary learners. The instruments underwent face and content validation by two experts in literacy and primary education to ensure clarity, developmental appropriateness, and conceptual alignment with engagement theory. The questionnaire data were used descriptively to identify general engagement tendencies and to triangulate classroom observations. They were not treated as standalone outcome measures but as complementary evidence supporting thematic interpretation. Given the descriptive and triangulation-oriented function of the instrument, the questionnaire was not designed to establish psychometric generalisation but to support interpretive analysis of engagement patterns observed in classroom contexts.

Data Analysis

Qualitative data from observations and documents were analysed using thematic analysis following Braun and Clarke's (2006) framework. The analysis began with repeated reading of field notes to achieve familiarity with the data. Initial codes were generated to capture recurring instructional strategies and student responses. These codes were then organised into broader themes corresponding to behavioural, emotional, and cognitive engagement categories. Cross-case comparison was conducted to identify similarities and differences among the five classroom contexts. This process enabled the identification of recurring pedagogical mechanisms through which narrative texts mediated engagement. Quantitative questionnaire responses were analysed descriptively through frequency distributions and mean tendencies. These results were interpreted alongside qualitative themes to enhance analytical depth and credibility.

Trustworthiness

Several strategies were employed to strengthen methodological rigor. First, data triangulation was achieved by integrating observations, instructional documents, and perception data. Second, thick description of classroom practices was provided to support interpretive transparency. Third, cross-case analysis enhanced the credibility of recurring patterns. Finally, analytical memos were maintained throughout the coding process to document interpretive decisions and reduce subjective bias. Given the exploratory nature of the study, the findings are presented as contextually grounded interpretations rather than statistically generalisable claims.

RESULTS

The analysis across five classroom cases reveals that children's literature functioned as a narrative-mediated pedagogical structure shaping behavioural, emotional, and cognitive engagement. Rather than operating solely as supplementary reading material, picture books served as instructional entry points through which teachers structured participation, affective connection, and analytical reasoning. Four recurring pedagogical mechanisms were

identified across cases: (1) narrative entry structuring, (2) dialogic interaction, (3) emotional anchoring, and (4) cross-curricular conceptual bridging. These mechanisms are presented below according to engagement dimensions while acknowledging their interrelated nature.

Narrative Structuring and Behavioural Engagement

Across cases, teachers consistently initiated lessons by positioning children's literature as a narrative entry point. Stories were introduced prior to conceptual explanation, enabling students to enter the lesson context through plot, character, and setting. Behavioural engagement was reflected in observable participation patterns, including voluntary responses, collaborative discussion, sustained attention, and task persistence. Students demonstrated increased willingness to respond to teacher prompts when questions were embedded within narrative contexts rather than abstract exposition.

For example, when teachers paused reading to invite prediction or interpretation, students actively raised hands and offered hypotheses about character decisions. These participatory behaviours were not limited to language subjects; similar patterns were observed in science and civic education lessons where narrative scenarios were used to introduce thematic content. Descriptive questionnaire data supported these observations. A majority of students indicated agreement with statements reflecting active participation and sustained involvement during story-based lessons. This convergence suggests that narrative structuring functioned as a behavioural engagement catalyst across cases.

Emotional Resonance and Affective Investment

Emotional engagement emerged as a prominent feature of literature-integrated instruction. Students frequently displayed affective responses such as laughter, empathy toward characters, and spontaneous commentary about personal experiences related to story events. Teachers intentionally selected culturally relevant picture books, enabling students to recognise familiar social contexts, local values, and relatable dilemmas. This cultural proximity appeared to strengthen emotional identification and classroom belonging.

Observation notes documented moments in which students verbally expressed concern for characters facing moral challenges or social conflicts. Such reactions extended beyond surface enjoyment and reflected emotional investment in narrative development. Student questionnaire responses similarly indicated positive affective tendencies, with many students reporting enjoyment and interest during story-based activities. These findings suggest that narrative texts created emotionally supportive learning spaces aligned with social and emotional learning principles.

Dialogic Interpretation and Cognitive Engagement

Cognitive engagement was primarily fostered through structured dialogic interaction. Teachers did not limit instruction to story reading; instead, they incorporated interpretive questioning, hypothetical reasoning tasks, and problem-solving activities linked to narrative situations. Students were prompted to analyse character motivations, evaluate decision consequences, and propose alternative solutions. These tasks required inferential thinking and perspective-taking, reflecting deeper intellectual investment beyond factual recall.

Across cases, teachers extended narrative discussions into conceptual domains. For instance, stories addressing environmental themes were used to initiate scientific reasoning about ecological responsibility. Similarly, narratives involving health-related dilemmas were linked to discussions of hygiene and personal well-being. This cross-disciplinary extension indicates that literature functioned as a conceptual bridge rather than a self-contained activity. Questionnaire responses revealed that students perceived these activities as helping them "think more deeply" and "understand lessons better," reinforcing observational interpretations of cognitive engagement.

Cross-Case Patterns: Narrative Pedagogy as an Integrative Mechanism

Although classroom contexts varied, cross-case comparison revealed consistent instructional patterns. Teachers employed narrative structuring to initiate engagement, dialogic questioning to sustain participation, and contextual bridging to connect stories with disciplinary content. Importantly, engagement dimensions did not operate independently. Behavioural participation often preceded emotional resonance, which in turn supported sustained cognitive reasoning. This interrelated pattern suggests that narrative pedagogy functioned as an integrative mechanism aligning engagement dimensions simultaneously.

However, the depth of cognitive engagement varied depending on the extent to which teachers scaffolded interpretive discussion. In cases where questioning remained surface-level, engagement tended to remain predominantly behavioural and emotional. This variation highlights the central role of teacher mediation in transforming narrative exposure into meaningful analytical learning. This interdependence reflects the dynamic interaction among engagement dimensions proposed in multidimensional engagement theory (Fredricks et al., 2004).

DISCUSSION

The findings of this study indicate that children's literature, when strategically integrated into classroom instruction, operates as a narrative-mediated pedagogical structure that shapes multidimensional student engagement. Rather than functioning solely as a literacy enhancement tool, literature served as an instructional bridge connecting behavioural participation, emotional investment, and cognitive reasoning within cross-curricular contexts.

Consistent with engagement theory (Fredricks et al., 2004), the results demonstrate that engagement dimensions are interrelated rather than isolated constructs. Behavioural participation—manifested through active responses and collaborative discussion—frequently emerged through narrative entry structuring. Emotional engagement developed as students identified with culturally resonant characters and scenarios. Cognitive engagement deepened when teachers scaffolded interpretive reasoning and linked narrative situations to disciplinary concepts.

Importantly, this study extends prior research that primarily associates children's literature with creativity and moral development by demonstrating how narrative pedagogy functions structurally within classroom interaction. The findings suggest that the pedagogical power of literature does not lie solely in its thematic content but in how teachers mediate narrative experiences through dialogic questioning and conceptual bridging.

The cross-case analysis further reveals that teacher mediation plays a decisive role in determining the depth of engagement. While narrative texts consistently stimulated behavioural and emotional responses, sustained cognitive engagement depended on the intentional design of interpretive and analytical tasks. This nuance contributes to engagement scholarship by illustrating that narrative exposure alone does not guarantee higher-order thinking; rather, it is the integration of guided inquiry within storytelling contexts that fosters deeper intellectual involvement.

Within the Indonesian educational context, the findings also highlight the potential of culturally contextualised picture books to strengthen classroom inclusivity. Students' emotional identification with familiar social and moral scenarios appeared to enhance affective belonging, which in turn supported participatory behaviours. This observation aligns with culturally responsive teaching principles, suggesting that narrative pedagogy can serve as a locally grounded engagement strategy.

Nevertheless, the study's exploratory design necessitates interpretive caution. Engagement was examined primarily through observational indicators and perception-based measures rather than longitudinal academic outcomes. Future research may expand this inquiry by incorporating learning achievement data, experimental comparison groups, or extended classroom observation periods to further examine the sustained impact of narrative-based instruction.

Overall, this study reconceptualises children's literature as an integrative engagement framework rather than a supplementary instructional resource. By systematically mapping behavioural, emotional, and cognitive dimensions within narrative-based pedagogy, the research contributes to a more structured understanding of how storytelling practices shape classroom learning environments. These findings suggest that narrative pedagogy may serve as a scalable engagement strategy in literacy-driven educational reforms, particularly in culturally diverse primary settings.

CONCLUSION

This study explored how Indonesian children's picture books were integrated into primary classroom instruction to foster behavioural, emotional, and cognitive engagement. The findings demonstrate that narrative-based pedagogy can function as a structured engagement mechanism when supported by intentional questioning, cultural relevance, and cross-curricular alignment. Rather than serving merely as literacy enrichment materials, children's literature operated as a pedagogical infrastructure connecting subject content with students lived experiences. The integration of storytelling across disciplinary contexts enabled teachers to mediate abstract concepts through relatable narratives, thereby promoting deeper cognitive involvement alongside emotional resonance.

The study contributes to engagement theory by highlighting the structural role of narrative mediation in shaping multidimensional engagement. It also underscores the importance of teacher competence in transforming literature from passive reading material into an interactive learning catalyst. However, engagement observed in this study was primarily measured through perception and classroom behaviour indicators. Future research should examine longitudinal academic outcomes and comparative text contexts to further validate the instructional impact of narrative-based strategies.

Overall, this study affirms that strategically integrated children's literature can enrich classroom ecology, provided that it is embedded within deliberate pedagogical design rather than implemented as an incidental activity.

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Historical Virtual Tour for Learning About the Yellow War in Lasem

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ABSTRACT

This study aims to develop the virtual tour of the 18th century Lasem History (VISUM) and its effectiveness in historical learning. This study used a design thinking approach, comprising five steps of empathising, defining, ideating, prototyping, and testing, to develop the VISUM for university students enrolled in the Indonesian Colonial History module. The 18th century Lasem History, as a learning material, was used to represent the complexity of early modern Indonesian history. The researchers integrated the historical method in the defined stage to compose historical learning material properly. The researchers also used various tests, ranging from validity tests and reliability tests to normality tests, to assess the effectiveness of the VISUM. After giving the tests, the results show a significant increase from 71.4 to 91.7 in the average scores. The finding also suggests that the virtual tour could improve the students' comprehension of complex historical content and historical thinking skills. Furthermore, the use of virtual tours could support the students to strengthen specific historical concepts of cause-and-effect analysis and historical significance.

Keywords: History education, Lasem, university students, virtual tour, Yellow War

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INTRODUCTION

Historical reconstruction helps a person to understand an event that occurred in the past. Over time, historical narrative could be displayed in the form of textual or visual historiography. A virtual tour could be used to reenact historical events

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based on its sites. The virtual tours can also be used as a medium to study history in depth. Through virtual tours, historical relics can be represented in a real form (Di Natale et al., 2020). The use of visual digitalisation in learning history can be a solution to the problem of history, which has been considered grey. By utilising digital technology, it can bring users to explore historical sites from inside the classroom. *Perang Kuning* (Yellow War) in Lasem, Central Java, could be promoted to be learned by the historical students in the module of Indonesian colonial history at the university level.

The Sino-Javanese cooperation in the context of the Yellow War in Lasem has represented an interesting cultural dynamic and historical events (Basiroen & Manuaba, 2022). Lasem, a coastal city on the North Coast of Java, became a strategic area that functioned as a port city since the Majapahit period. In addition to the maritime culture, a 7th-century boat wreck can be found in Lasem and its surroundings (Unjiya, 2014). This proves that the maritime culture in Lasem existed before the Majapahit era. However, during the Majapahit period, Lasem became the centre of economic development as well as a meeting point between Chinese, Arab, and Javanese cultures (Adhitya et al., 2023; Atabik, 2016).

In the middle of the 18th century, Lasem experienced the war against the Dutch colonial masters. Administratively, Lasem was under the Mataram Kingdom during the 17th century. The Dutch attempted to control the North Coast of Java. When the Dutch invaded Mataram, the Javanese ruling class did not counter their invasion. The Lasem people did not want to transfer their trading control to the Dutch. In 1741, the Lasem community, led by Oei Ing Kyat, Raden Panji Margono, and Tan Sin Ko, rebelled against the Dutch (Wijaya et al., 2024). The 18th-century Yellow War, not merely dealing with the colonial war, but also representing the cooperation between the Chinese and the Javanese to gain their shared aim and have freedom from the Dutch coloniser. Their alliance could be a lesson on cultural tolerance for historical students.

The cultivation of historical learning through the integration of digital devices can be an answer to the challenges of the disintegration of values and culture for the students (Marpelina, 2024). Showing historical sites, integrated with face-to-face interaction, could increase the depth of understanding of historical learning (Zhang et al., 2023). The incorporation of digital tools and interactive learning approaches can also change the old paradigm of history learning. Marpelina (2024) states that the selection of digital technology and the utilisation of interactive learning approaches can affect the depth of students' understanding in learning. As technological development and learning innovation continue to develop, they will also have an impact on the quality of history learning.

Virtual tours, as a medium, could facilitate an interactive learning experience. The integration between virtual tours and the historical material of the Yellow

War could support historical teaching based on the 21st-century teaching skills of creative thinking, critical thinking, communication, and collaboration. One of the ways to stimulate those teaching skills is to develop interactive visual media (Harshbarger, 2016). The visual media, such as virtual tours, could bridge the students to the learning material (Susianti, 2024). Virtual tours could realise actual creation and communication. This media would encourage students' attention and active engagement to create a progressive learning environment (Ariesta et al., 2024).

Previous studies have already studied the use of virtual tours in bringing history to real life. Therefore, virtual tours could be a historical learning innovation and useful to communicate and reenact past events (Wijaya, 2015). The visualisation of historical traces, evidence, and artefacts could strengthen the imaginative thought and in-depth understanding of the event. The use of virtual tours cannot only ease the learning material but also foster the learner's historical empathy and understanding of the age (Ofianto et al., 2023b). Schaper et al. (2018) demonstrate that digitally reconstructing cultural heritage sites and artefacts, such as those related to the events of the Spanish Civil War, can enhance learning about the past. In addition, Argyriou et al. (2020) argue that the 360-degree visualisation has great potential as an engaging experiential medium, especially in learning about cultural heritage.

Applying a similar technique to historical events is a visually appealing and informative option for students. However, the existing studies do not integrate virtual tour technology to the local historical event in the context of the teaching and learning process. They frequently digitalise the existing museum to attract online viewers (Aurindo & Machado, 2016; Bandarsyah & Sulaeman, 2021; Nafi'ah, 2023; Syukur et al., 2022). This study considers the student's need analysis as a pedagogical framework to design and implement the Virtual Tour of the 18th century Lasem History. The use of the virtual tour could elevate to the students' historical understanding, as revealed by Chotimah et al. (2024) and Agustinova et al. (2025), and enrich the diversification of the historical learning media. This study, therefore, tends to utilise the potential of Virtual Tour in learning the history of the 18th-century Lasem history, especially the Yellow War in Lasem. Therefore, this study focuses on the development of a virtual tour learning media for the history of the Lasem Yellow War. This study also aims to assess the effectiveness of the VISUM media in supporting the critical thinking skills of students in the History Department of State University of Malang.

LITERATURE REVIEW

Historical Thinking

History could be defined as past events. However, a historical event arises due to a construct carried out by a writer, as a story (Kartodirdjo, 1992). History itself is created through the creative process of a historian in interpreting historical evidence, which then produces a story (Seixas & Morton, 2013). In the context of

education, historical events can be used as a fundamental component to shape students' understanding of the meaning taken from past events. The historical meaning, also known as the historical pattern, could be a compass to direct the present and chart the future (Kindenberg, 2021; Wineburg, 2001). History also builds students' critical understanding of an event, involving thinking historically (Seixas, 2017).

Seixas and Morton (2013) explain six concepts in historical thinking, including historical significance, evidence, cause and consequence, the ethical dimension, continuity and change, and historical perspectives. Historical thinking skills include the ability to analyse and understand cause-and-effect relationships in historical events, as well as to identify continuity and change that occur over time.

Causal thinking in a historical context refers to the ability to identify and analyse relationships between events, actions, and outcomes that occur within a specific time and space. According to Sukma (2023), effective learning must be able to develop students' critical and analytical thinking skills. They can understand how historical events are interconnected and influence each other. For Fitria et al. (2022), developing the potential of historical heritage can help students understand the historical context and its impact on contemporary society. Thus, learning media development can provide a broader context for students to understand causal relationships in history.

Furthermore, continuity in historical thinking encompasses an understanding of how past events influence current and future circumstances. In this context, Astuti and Muslim (2018) argue that the use of interactive media can enhance students' understanding of continuity and change in historical events. The students need to understand that history is not simply a series of isolated events, but rather an ongoing process that shapes the identity and culture of a society. Therefore, the learning media must be able to present information that not only explains historical events but also relates to broader social, political, and cultural contexts.

Historical thinking skills also involve the ability to interpret and evaluate historical sources. Effective learning strategies must involve critical analysis of historical sources to help students understand different perspectives and construct strong arguments (Inayah, 2022). In this regard, the learning media must incorporate a variety of historical sources, including documents, images, and narratives, which can assist students in critically analysing and evaluating information. In this way, students not only learn about historical events but also how to think critically and analytically when dealing with historical information.

The causality and continuity of thinking skills in history education is also essential. Muhammad (2023) states that the use of historical books as teaching materials can train students' chronological thinking skills. These chronological thinking skills are crucial for understanding the sequence of events and how they relate to each other. Therefore, the learning media developed must be designed in such a way that it is

easy for students to follow the historical flow and understand the interrelationships between events.

In the context of developing learning media, it is important to consider interactive and engaging approaches. Karmedi et al. (2021) suggest that the use of technology, such as virtual reality, can enhance students' learning experiences by providing direct access to historical sites. This suggests that integrating technology into history learning can help students engage more effectively and better understand the historical context. Therefore, the learning media must consider interactive elements that can enhance student engagement in the learning process.

To support historical thinking skills, learning media should also include reflective questions and assignments that encourage students to think critically about the relationship between historical events and their impact on contemporary society. Fitri and Yefterson (2021) demonstrate that the use of learning media can help students to identify change and continuity in historical events. Therefore, learning media should include elements that encourage students to reflect on and analyse the historical events that they are studying.

Virtual Tour in Education

A virtual tour is a digital depiction of a place that can allow users to explore the location (Nicolaidou et al., 2022). In educational context, virtual tours have transformed the learning medium beyond the physical constraints of classrooms by integrating immersive visualisation. Some previous studies also mention several applications for virtual tours for educational purposes. Those are for the virtual labs (Cardona et al., 2023), cultural tourism education (Chiao et al., 2018), education in second life (Calongne & Hiles, 2007), digital branding tool for higher education (Aryani et al., 2022), and synchronous distance education (Partin & Worch, 2011).

In the process of teaching and learning, the utilisation of virtual tours integrates digital visualisation. A virtual tour of the Lasem history is considered to have significant potential to improve student understanding. Through a virtual tour, students can explore the site location digitally, in this case, the historical sites of the Yellow War in Lasem. Even, the students could explore inaccessible and endangered places, such as Dutch Factory in the Lasem Mount. They also could experience contextual authenticity through panoramic imagery. Virtual tours can provide students with broader access and encourage their involvement in understanding history through innovative media (Pasaribu et al., 2022).

Virtual tours can be used as an effort to improve students' ability to process historical information (Safitri, 2021). The historians should also have the ability to analyse the historical data (Kuntowijoyo, 2018). Thus, the use of virtual tours also influences the improvement of historical thinking skills and students' learning outcomes (Rosmah et al., 2023). The virtual tours could allow users to experience new learning experiences.

Lasem has a long history, especially the Yellow War. It has various sites that can be used as learning material on a virtual tour. By incorporating this content into the virtual tour, students not only learn from textbooks but also get a real visual overview of historical locations related to the Yellow War. This allows students to understand the material easily (Doğan, 2023). In addition, the integration of virtual tour technology in learning history is a more modern and relevant approach to the students' learning style.

Integrating virtual tours to the learning media is also useful in multidisciplinary learning. In the virtual tour of Lasem history, it covers all aspects of life comprising socio-political and cultural history. Kartodirdjo (1992) also reminds that historical understanding requires cross-disciplinarity, using a multidimensional approach in the historical method. Thus, this creates a learning experience that applies critical analysis and deep understanding. The utilisation of virtual tours could advance the progress of history education, compared to other educational fields. In the learning material of the yellow war history, the virtual tour could facilitate broader and deeper access for students to understand the origin of cross-cultural history and heritage in Lasem (Purwanto & Titiek, 2017).

METHODOLOGY

This study used a design thinking approach as a Research and Development (R&D) model. Design thinking is used to solve a problem, focusing on understanding and creativity to create an innovation (Lewrick, 2023). This approach addresses the emotional impact, aesthetics, and interactions that connect the system with the users. Thus, the innovations look at the conditions of users (history students). The design thinking process includes several stages of empathise, define, ideate, prototype, and test (Figure 1).

The first is to empathise, which aims to understand the needs and challenges faced by potential users, in this case, history students who take the Indonesian Colonial

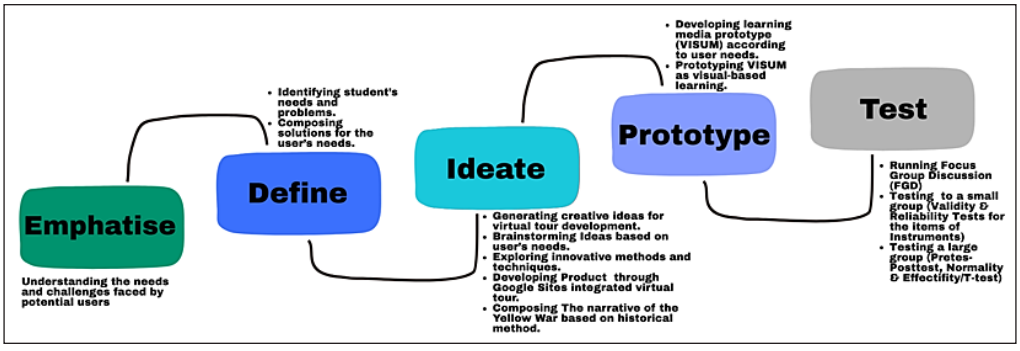

Figure 1. The steps of the design thinking approach to develop the VISUM
Source: Modified from Soegaard (2018)

History module. The data were collected through analysing the needs of prospective users, obtained through questionnaires and observations. The respondents were students in the History Department of State University of Malang, taking a course in Indonesian History during the Colonial Period. For the ethical considerations, the researchers conducted research in accordance with established ethical guidelines in Indonesian higher education system. The research protocol was reviewed and approved by the relevant ethics committee. The consent was also obtained from all respondents prior to data collection. At the time of the study, the students were in their second year. To determine the product to be developed, the researchers conducted a needs analysis, including materials, media, and student learning styles. The needs analysis revealed that students needed learning media that could effectively support their learning.

After collecting data on the need analysis, the next step is to define it. At this stage, we tried to find out the problems and the users' needs. In the defined stage, the researchers composed an alternative solution to cope with the problems and needs. After defining the needs and problems, the researchers offered their creative ideas for the users' problems and needs. Those ideas would be processed in the form of a prototype before being realised as a product. The researchers composed the learning material based on the historical method. The researchers used all available data comprising the Dutch archives and local chronicles, mainly *Carita Sejarah Lasem* (The Chronicle of Lasem). The researchers narrated the learning material in a more accurate and in-depth way. The researchers compared the colonial records with the local chronicles to ensure the accuracy, reliability, and balance of the reconstructed historical narrative of the Yellow War.

After the product had already been produced, it was then validated by two experts of learning media and learning material. They also gave some feedback to revise the existing product. Several experiments were also needed to determine the product's effectiveness as a learning medium. Those experiments were conducted in small and large groups. A small group of experiments was conducted to determine the validity and reliability of the test instrument for the larger test. Samples were taken to assess the validity and reliability of the test instrument based on criteria determined by the researcher (purposive sampling). The criteria were selected from students deemed to have superior abilities. From a class of 36 students, the sample was taken from 10 students with the best achievements. After the instrument was valid and reliable, the researcher conducted a large-scale test to determine the effectiveness of the VISUM learning media as a support for teaching Indonesian history during the colonial period.

RESULTS

It is necessary to follow the design thinking model (empathise, define, ideate, prototype, and test) to conduct research and development (R&D) of a virtual tour of 18th-century Lasem History, as follows.

Empathise

This step was taken with the main objective of analysing user needs and problems in the context of history learning (Nasution & Nusa, 2021). The needs analysis process was carried out by distributing questionnaires to students who took the Indonesian Colonial History module as the research subject. Of the 36 students who responded, 88.2% stated that they needed learning media that could visualise historical sites. This finding shows a gap between abstract learning materials and students' needs for concrete representations that are easier to understand. Furthermore, the diagnostic test results indicated that most students had a visual learning style. Visual learning style is a category of learning styles that emphasises an individual's preference for the presentation of information in visual representations such as pictures, diagrams, graphs, maps, and symbols. Students with this learning style tend to find it easier to understand material through pictures, maps, videos, and virtual tours than through descriptive text alone. Thus, the use of visual-based learning media such as VISUM is considered capable of meeting students' learning needs because it is in line with the characteristics of their learning styles and can increase the effectiveness of history learning. Furthermore, the integration of visual media also has the potential to encourage higher cognitive engagement, facilitate contextual learning, and strengthen students' ability to develop historical thinking skills.

Define

After the empathise stage, the define step aims to identify the student's needs and problems (Dewi et al., 2022). Thus, the identification of needs and problems could ease the research process to find solutions that are relevant to the user's needs. If we look at user needs, the developed product is a visual learning medium. Students, having a visual learning style, tend to understand the material better if there is a visual display. Without visual instructions in learning, students will be bored in learning (Clarke et al., 2006). In learning history, visual aspects can also help students to imagine historical remains and events (Garvey & Krug, 2015).

Virtual tour is one of the learning media that can create new experiences for its users (Aristeidou et al., 2022). By using virtual tour learning media, students can easily understand the material to be taught. In addition, the background of students who have a visual learning style also supports the use of virtual tours as a learning medium. Therefore, the researchers strive to develop a virtual tour with the material of Yellow War History to address the user's needs.

Ideate

This stage allows the researchers to create creative ideas and an alternative for the development of the virtual tour. The researchers' ideas can be used as a basis for developing products according to the users' criteria. At this stage, researchers could explore innovative techniques and methods to develop a product (Ye, 2024). In developing a product, we compose a Google-

based website (Google Sites), integrated with a virtual tour. Before developing the website, the researchers re-narrate the historical event of the Yellow War, based on the historical primary sources of *Carita Sejarah Lasem* (the Lasem Chronicle) as well as the Dutch archives and chronicles. We also revisit historical sites related to the Yellow War. The researchers take photos in a 360-degree picture at each predetermined point. Then, the researchers compile either textual or visual data before displaying it on Google Sites.

At this stage, we also compose the historical material of the 18th-century Lasem History for the development of virtual tours. The researchers visualise the historical sites related to the Yellow War in Lasem. Those sites are the diorama of Yellow War Lasem in Cu An Kiong Temple (Figure 2), the Lasem Mosque (Figure 3), and the Panji Margono Statue inside the Gie Yong Bio Temple (Figure 4).

In developing Google Sites, the researchers, as product developers, have four working steps. First, the developers



Figure 2. Virtual tour of the diorama of Yellow War in Cu An Kiong Temple
Source: Authors' Document



Figure 3. Virtual tour of the Lasem Mosque
Source: Authors' Document



Figure 4. Virtual tour of the statue of Panji Margono inside Gie Yong Bio Temple
Source: Authors' Document

create a Google Sites account and select a template on the Google Sites page. Second, the developers edit and add content. After setting up the main page or homepage, the developers add textual, visual, and audio-visual information related to the Yellow War and the history of Lasem in the 18th century. The developers also add virtual tours and digital maps to Google Sites. Third, the developers customise their appearance by changing the theme and adjusting the colour and font style accordingly. In addition, developers also arrange the layout of Google Sites such as Home, History, Tourist Destinations, Culinary, Geography, Virtual Tour, Digital Maps, Videos, and Profile. The content on each page can be text, photos, videos, digital maps, Virtual Tours, Google Maps, or website links. The developers, lastly, preview and publish it to the public.

Prototype

This stage directs the researchers to create a prototype of the learning media, based on the users' needs (Stewart, 2011). Product development is carried out by considering the needs and problems of potential users (Dukała et al., 2023). Based on user needs analysis, we are trying to develop a website-based learning media integrated with a virtual tour called VISUM. VISUM is a web-based learning medium designed to emphasise visual aspects. The main feature of this medium is the Virtual Tour. Although the main feature of this medium is the virtual tour, it also has various advantages for conveying historical information in learning. The first page of VISUM presents an overview and summary of the entire VISUM display. This display functions as user navigation to understand the flow and scope of information contained in VISUM. The next page is about history. This page contains a long narrative about the history of Lasem, particularly the Lasem Yellow War that occurred in the 18th century. This page broadly covers the geopolitics of Lasem in the 18th century, social life, culture, economy, and the events of the Lasem Yellow War in the 18th century. The selection of material and time period used in VISUM is contextualised with the secondary

education curriculum. In addition, the material on the Lasem Yellow War is rarely highlighted in colonial historiography. By adding this material to the learning process, it can provide students with new insights into the historiography of Lasem. Thus, VISUM can improve students' analytical skills in relation to the influence of global historical events on local historical events.

In the next section, VISUM presents a list of historical sites in Lasem that serve as a guide for users to identify important locations related to historical events in the region. This list not only serves as an inventory of historical sites but also as an educational tool that helps students understand the connection between space, events, and the collective memory of the Lasem community. Furthermore, VISUM also displays a page on local cuisine that provides information about Lasem's specialty foods. The presence of this culinary content is not only informative for tourists but also emphasises the importance of material culture as an integral part of local historical studies. Furthermore, VISUM provides a "Geography" page that presents information about accessibility to Lasem from various major cities such as Jakarta, Semarang, Surabaya, and Malang. This information has strategic value because it shows the geographical relationship between urban centres and historical areas, while also strengthening understanding of mobility and communication networks in both historical and contemporary contexts. Thus, VISUM not only serves as a medium for learning history but also as a multidimensional tool that integrates educational, cultural, and geographical aspects to enrich the learning experience of students.

The most important part of VISUM as a learning medium that provides experiences is the virtual tour feature. This feature is designed to provide an interactive and contextual history learning experience. Through virtual tours, students can explore various historical sites without having to visit them. This provides an opportunity to access more in-depth historical knowledge because it presents actual visualisations of historical sites. For students who have limitations in understanding written text, this feature can be a platform for students with a visual learning style. To support the process of understanding the geospatial locations of important sites in Lasem, VISUM is also equipped with an interactive digital map feature. This feature allows users to explore the strategic locations of historical sites in Lasem. With this feature, VISUM is not limited to classroom learning. It can also be used for field learning. In fact, VISUM can also be used as a guide for history-based tourism activities.

To clarify the historical narrative of each site contained in VISUM (Figure 5), this website contains short documentary videos that provide explanations of each site. The videos contained in this feature provide information about the historical context of the sites related to the Lasem Yellow War in the 18th century. These features not only serve as a means of exchanging information but also as a learning tool that encourages active student participation, contextual



Figure 5. The display of Learning Media VISUM
Source: Authors' own work

understanding, and the strengthening of historical thinking skills for students.

Test

The last step, which is the test, aims to evaluate the effectiveness of the product in historical learning. In addition, there are several experiments to be conducted before testing the students. Those experiments are given to a small and large group of students. Before doing the experiments, the researchers also run the Focus Group Discussions (FGD) to receive inputs concerning the detailed information related to the Lasem history from the local perspective (Figure 6). Those inputs could maximize the developed product. The participants of FGD consist of researchers,



Figure 6. Focus Group Discussion in Lasem on April 23, 2024
Source: Authors' Document

historians, and cultural experts from Lasem. The FGD also aims to refine the product before testing it on students. Based on the FGD, several inputs were received from participants. Several points need to be revised to ensure the completeness of the narrative and the chronology of historical events in the media. Additionally, the use of local sources, such as *Carita Sejarah Lasem*, is used to examine the history of the Yellow War from a local perspective.

Validity

This study used a questionnaire instrument to be administered during the field of expert trials and product expert trials. The questionnaire, which already had answers, was then compiled using a Likert scale. The used scale was a score with intervals of 1-4. The use of a scale with intervals of 4 was to obtain more objective answers from respondents (Likert, 1932). The used formula to determine the percentage was as follows:

$$\frac{\Sigma X}{\Sigma X1} \times 100\% = \text{Percentage} \qquad [1]$$

Notes:
X: the gained score
X1: the maximum score

From the distributed questionnaire, the learning media expert gave a score of 33 out of 36. This score resulted in a percentage of 91.66%. Meanwhile, the learning material expert gave a score of 58 out of 64. Therefore, the total result was 90.625%. Researchers also conducted a validity test on each question item (Table 1).

The question item is valid if the calculated r value is equal to the table r and the significance value (sig) is <0.05. The

Table 1
Validity test for the question items

Q	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Q1	1.000	.167	.802**	.250	.612	.167	.802**	.089	.802**	.000
Q2	.167	1.000	-.089	.250	.102	.583	-.089	.535	.356	.408
Q3	.802**	-.089	1.000	.089	.218	.089	1.000**	.048	.524	.518
Q4	.250	.250	.089	1.000	-.102	.250	.089	.802**	.089	.408
Q5	.612	.102	.218	-.102	1.000	.102	.218	-.218	.764*	.000
Q6	.167	.583	-.089	.250	.102	1.000	-.089	.089	.356	.816**
Q7	.802**	-.089	1.000**	.089	.218	-.089	1.000	-.048	.524	-.218
Q8	.089	.535	-.048	.802**	-.218	.089	-.048	1.000	-.048	.218
Q9	.802**	.356	.524	.089	.764*	.356	.524	-.048	1.000	.218
Q10	.000	.408	-.218	.408	.000	.816**	-.218	.218	.218	1.000

Source: Authors' own work
Notes:
**: significance on the level of 0,01 (2-tailed)
*: significance on the level of 0,05 (2-tailed)
Q: question
r: coefficient value of correlation

question is a valid question if the calculated r > table r (because there are 10 questions then the table r = n - 1 or table r = 10 - 2 = 8, so the table r is 0.542. Based on the significance table, question numbers 1 to 10 are valid because the calculated r is greater than the table r.

Reliability

Reliability testing was used to assess the validity of a research instrument. A questionnaire was considered valid if a person's answers to the questions were consistent or stable over time. An instrument was considered reliable if its Cronbach's alpha value was >0.6. The results of the reliability test showed Cronbach's alpha value of 0.773, which was greater than 0.6. Therefore, the instrument can be considered reliable (Table 2).

Table 2
Reliability statistics

Reliability Indicator	Value
Cronbach's Alpha	0.774
Cronbach's Alpha (Based on Standardized Items)	0.773
N of Items	10

Source: Authors' own work

Normality and Effectivity

Thirty-five students are tested, both pre-test and post-test, using the multiple-choice test based on assessment indicators (see Table 3). This success indicator is adapted from Seixas and Morton (2013) concept of historical thinking. They argue that, to understand a past event, one should think like a historian by viewing the event with the perspective and significance of the past. By instilling this mindset, students can see

Table 3
Assessment indicators for students' multiple-choice tests, developed from Seixas

No	Indicators	Multiple-Choice Tests
1	Students are able to analyse the impact of the Dutch monopoly policy on the socio-economic life in Lasem.	What was the main impact of the VOC's trade monopoly policy on the socio-economic conditions of the Lasem people in the 18th century? a. Improving public welfare through free trade b. Sparking popular resistance due to limited access to trade c. Opening new job opportunities for the people of Lasem d. Improving diplomatic relations between Mataram and the VOC
2	Students are able to explain the strategic and military factors influencing the cause and end of the war.	Why did Oei Ing Kiat and Panji Margono decide to withdraw their troops after the attacks on Juana and Jepara? a. They had achieved a major victory in Rembang b. They wanted to develop a new strategy for the next attack c. The defeat of the militia and the superior strength of the VOC forced them to retreat d. Pakubuwono II ordered them to cease resistance

Table 3 (*continued*)

No	Indicators	Multiple-Choice Tests
3	Students are able to identify and explain the military tactics used in the resistance against the Dutch.	What military strategy was used by Laskar Dampo Awang in the resistance against the VOC in Rembang, Juana, and Jepara? a. Attack from the interior and surround the city from all directions b. Use guerrilla warfare and stealth to approach the enemy c. Attack head-on with a large force in the city center d. Wait for assistance from the Mataram kingdom before launching an attack
4	Students are able to analyse the changes in the social structure in Lasem after the locals failed to defeat the Dutch.	What was the impact of the defeat of the Lasem people on the social structure of their society after 1751? a. The people of Lasem experienced mass slaughter without a trace. b. The Chinese were moved to the city and strictly monitored. c. Lasem became the main administrative center of the VOC. d. The natives gained more power than before.
5	Students are able to take the values of struggle and unity from the resistance against Dutch colonialism.	The main lesson that can be learned from the resistance of the Lasem people against the VOC is? a. Resistance against colonialism will only lead to destruction. b. Unity across ethnicities and groups can be a force against oppression. c. The VOC is the only party with the right to control trade in Java. d. Puppet governments are more effective in confronting colonialism.
6	Students know about the Yellow War in Lasem and its impact on society.	How did the Yellow War end in Lasem? a. Victory of the Lasem people b. Victory of the VOC and defeat of the Lasem people c. Peace agreement between the VOC and the Lasem people d. Withdrawal of the VOC from the Lasem region
7	Students are able to explain the involvement of the Chinese community in the resistance against the Dutch.	The role of the Chinese community in the Yellow War in Lasem can be linked to? a. Their dominance in the VOC colonial government b. Dissatisfaction with VOC policies that restricted their trade c. Their desire to gain political power in the Mataram kingdom d. VOC support for their trade ventures
8	Students are able to identify the main causes of the Yellow War in the context of colonial history.	What was the main trigger for the Yellow War in Lasem in the 18th century? a. People's resistance to the VOC's trade monopoly b. Power struggle between Javanese kings c. The people of Lasem's desire to join the British d. Conflict between natives and Arab merchants

Table 3 (*continued*)

No	Indicators	Multiple-Choice Tests
9	Students are able to describe the impact of the conflict between the people of Lasem and the Dutch.	One of the social impacts of the Yellow War in Lasem was? a. The increasing number of Chinese people in Java b. The decreasing influence of the VOC in the archipelago c. The decline in public trust in local leaders d. The increasing trade relations between Lasem and the VOC
10	Students are able to explain the Dutch interests on the North Coast of Java, especially Lasem.	Why was the VOC so interested in controlling Lasem? a. Lasem is an important trading and shipping center on the north coast of Java. b. Lasem had gold mines that the Dutch East India Company (VOC) coveted. c. Lasem was the administrative center of the Mataram kingdom. d. Lasem had strong diplomatic relations with England.

Source: Authors' own work

the implications, impacts, and values that can be taken from past events.

As a result of implementing learning using VISUM, quantitative findings were obtained which showed a significant increase in student learning achievement. The average score achieved by students in the pre-test stage was 71.4, while in the post-test stage it increased to 91.7. However, to find out whether the collected data is normal or not. Researchers conduct a normality test as a basis for conducting an effectiveness test (T-test). If the sigmoid > 0.05 = normal, however, if the sigmoid < 0.05 = not normal, the results of the normality test that have been carried out are (a) Sigmoid in the Shapiro Wilk pretest shows a value of 0.034 < 0.05 so that the data distribution is not normal. (b) Sigmoid in the Shapiro Wilk posttest shows a value of <0.001 < 0.05 so that the data distribution is not normal (see Table 4).

Based on the normality test that has been conducted, the collected data shows abnormality. Therefore, the Effectiveness test is conducted using the non-parametric Mann Whitney. If the Asymp. Sig value (2 tailed) <0.05, it is concluded that there is a significant difference. Meanwhile, if the Asymp. Sig value (2 tailed) > 0.05, it is concluded that there is no significant difference. From the test that has been

Table 4
Normality test

Class	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	.192	36	.002	.934	36	.034
Posttest	.252	36	< .001	.774	36	< .001

Source: Authors' own work

conducted, the Asymp. Sig value (2 tailed) is <0.001, which indicates that there is a significant difference so that the results of the pretest and posttest that have been carried out indicate that the learning media is effective (see Table 5).

Table 5
Table of T-test

	Result
Mann–Whitney U	214.000
Wilcoxon W	880.000
Z	-5.010
Asymp. Sig. (2-tailed)	< .001

Source: Authors' own work

DISCUSSION

It is undeniable that technological development has an impact on historical learning innovations. The existence of innovations in history learning is one of the means to support the success of learning. However, in the context of the Indonesian colonial history module, few learning innovations have been developed yet. Therefore, the development of learning innovation is needed in history learning, especially in the material on the 18th-century Lasem war, to increase the effectiveness of historical learning in the module on Indonesian colonial history.

Based on the needs analysis conducted, 88.2% of the 36 students require visualisation in historical learning. When the researchers conducted preliminary observations, there was a student stating, "visualisation in learning will be meaningless if the historical data and visual form are not real; it will actually cause distortion of events." The researchers suggest that VISUM learning media should be developed because it will be mainly focused on visualisation-based learning. In addition, it also strengthens the aspect of historical narrative. Referring to Ofianto et al. (2022), history learning media that is appropriate to students' needs can improve chronological thinking skills. Chronological thinking skills are part of historical thinking skills (Seixas, 2017).

After analysing and identifying the students' needs, the researchers composed the learning material based on the historical method. The researchers exploit all available data from either primary or secondary sources. Reading the Dutch archives and local chronicles also allows the researchers to narrate the learning material in a more accurate and in-depth way. Few researchers narrate the learning material by following the historical method. Most of them focus on the aspects of media display and visualisation. They believe that interesting media could attract students to learn theory (Anderson, 2006; Barsch & Mathis, 2020; Insani et al., 2023).

However, history would be labelled as the material of redundancy and memorisation if we merely compose the same information as already written in the textbook. The use of primary sources is pivotal to providing new information for the students. One historical narrative that has not been widely written about in Indonesian historiography is the *Geger Pecinan* (The Chinese War) in Lasem, in the north coast of central Java. The strategic Lasem developed as an

economic center and a stage for cultural diversity. Lasem is known as a city with a long history involving interactions between Javanese and Chinese cultures, as well as global cultural influences. At that time, social life in Lasem was marked by the presence of a Chinese community that had settled for several generations, mixed with the Javanese (Wijaya et al., 2025). The relationship between these two communities was dynamic and mutually influential. Recently, people of Lasem celebrate the cultural crossroads and social tolerance in public spaces such as markets and social events (Astuti et al., 2019; Wijaya et al., 2025).

Their cooperation was strengthened under the Dutch threat. The Dutch imposed quotas on Chinese immigrants, considering the Chinese had already controlled the economy of Batavia. The Dutch started to persecute and murder the illegal Chinese in Batavia. In 1740, Chinese fled to the east of Batavia, including Lasem (Figure 7), where they were welcomed by Raden Panji Margana and Oey Ing Kiat. These refugees united with the Javanese community in Lasem to resist the Dutch. This alliance marked the beginning of a series of wars between the Chinese Javanese against the Dutch and its allies (Daradjadi, 2013).

The narrative of the Lasem War as a textual historiography is accompanied by a series of visual and audio-visual data. All data were displayed on a Google-based website (Google Sites) entitled VISUM (Virtual Tour of the 18th Century Lasem History). In the VISUM, the researchers integrate the textual content, 360-degree pictures, maps, and other related audio-visual content into Google Sites. Various forms of information are provided to the students, considering they have their own learning styles. By utilising virtual tours, users can be directly involved with sites related to the Yellow War in Lasem (Poetry, 2021). Virtual tours can be used as a medium to know the Lasem history as a trading centre for centuries. The students could reenact the process of Sino-Javanese

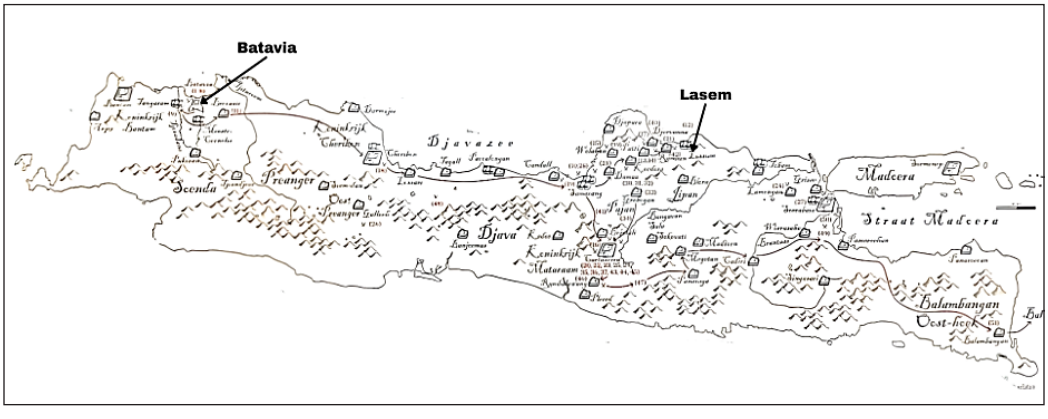

Figure 7. Lasem within the wider Dutch conflict zone from 1740 to 1743
Source: Daradjadi, 2013

interaction in Lasem by observing the related sites. Visualising the material culture in Lasem could help to realise the past event (Ilamsyah et al., 2020). The use of virtual tours in an educational setting could also support contextualised learning and overcome geographical constraints (Figueroa Jr, 2023).

Wibowo et al. (2023) point out that virtual tours-based websites are effective for use in the teaching and learning process. Websites that contain sources and content of historical information also have the potential to improve historical thinking skills (Widiadi et al., 2022). For this study, the use of VISUM is quite effective as a learning medium for historical students in higher education. Based on the results of the pre-test and post-test, the students' historical thinking skills have significantly improved. It means that VISUM development meets the students' needs. During the pre-test, the students depend on their prior knowledge when responding to some multiple-choice tests during the Lasem War. Their result is an average score. However, after reading VISUM, their score increases dramatically.

The posttest results have a higher mean rank (48.56), compared to the pretest results (24.44). The Mann-Whitney U test statistic value is 214.00 with a Z value of -5.010 and an asymptotic significance (2-tailed) of $p < 0.001$. These findings indicate that there is a statistically significant difference between the pretest and posttest results. This shows that the use of VISUM as a learning medium is effective. This effectiveness lies in their ability to provide contextual, interactive, and immersive visual representations, making it easier for students to relate factual knowledge to the spatial and visual experiences of the historical sites being studied. Furthermore, this improvement in achievement also contributes to developing historical thinking skills. Abidin et al. (2020) also argue that the use of virtual tours provides a deeper understanding of historical material and contextual experiences. One of the students also argues that "the use of virtual tours could strengthen specific historical concepts of causality and historical significance".

In learning history, students should possess the skills to think, read, and analyse historical sources (Ofianto et al., 2023a). These skills are the foundation for students to learn from historical events. Analysing historical sources indirectly familiarises students with analysing the causes and effects of past events (A. Widiadi, 2021). However, to improve these skills, appropriate learning media is required. Ofianto et al. (2023a) shows that utilising Virtual Field Trips (VFT) based on historical events and primary sources can improve these skills.

Besides cause-and-effect analysis, historical significance is a key component of historical thinking, emphasising students' ability to understand the importance of events, figures, and historical sites (Seixas & Morton, 2013). To understand the significance of historical relics from the past, fundamental knowledge of those events is required. Through virtual tour-based learning, students can see historical relics in real life. The use of virtual field

trip-based learning media can stimulate students' experiences in directly accessing historical sites (Ofianto et al., 2023a). Experiential learning can enhance students' understanding of the relevance of the relationship between the past and the present (Andresen et al., 2020). Understanding historical context and significance can improve one's analytical skills regarding the importance of past information to the present (Weimann, 2022).

The VISUM, as an integrated visual and textual learning medium, aims to encourage students to use their imagination to think about past events (Garvey & Krug, 2015). Students should use it to picture the past and bring its values to the present life. It helps them to understand the spirit of age and see historical events from different perspectives. Imagination also allows for more engaging learning and establishes critical thinking. Students could connect the past with the present and think like historians. Virtual tour is a dynamic learning medium and continues to grow; therefore, it has the potential to provide a more real learning experience. By utilising virtual tour media as learning, it could impact the future of education.

CONCLUSION

This study produces a virtual tour-based learning media on the Yellow War in Lasem. Briefly, the history of Lasem cannot be separated from the Yellow War. This conflict has taught the importance of resolving disputes peacefully and building mutually beneficial relationships for all parties. As a historical event, the Yellow War in Lasem is an important lesson for maintaining peace and harmony between ethnicities and cultures. The researchers successfully documented all the yellow war sites in the form of a virtual tour. All 360-degree images were embedded in Google Sites entitled VISUM (Virtual Tour of the 18th Century Lasem History). The researchers also validated the learning material and media in the development of VISUM. Validation was carried out by two experts. Various inputs related to the technical aspects of map display and the addition of primary sources greatly helped researchers to improve VISUM. The researchers also held FGD with Lasem historians. The researchers received a lot of input related to renarrate the Yellow War properly. The researchers then revise the VISUM based on suggestions and comments from material experts, media experts, and Lasem historians. In addition, the researchers also tested the effectiveness of using VISUM in learning Indonesian colonial history. It was found that VISUM is effective in supporting historical thinking skills.

The virtual tour is not only a means of conveying historical information but also plays as an acculturative medium for fostering tolerance values. This study suggests that the next developer should integrate virtual tours into historical learning in higher education. Virtual tours could bridge the gap between historical narratives and real experiences. However, the students should be accompanied by using VISUM effectively. Some students need further explanation related to either textual or

visual historiography in the VISUM. The lecturers should also prepare the printed historiography if the learners do not have adequate digital devices or stable internet access.

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Enhancing the Utilisation of the "Platform Merdeka Mengajar" to Empower Primary School Educators as Agents of Educational Excellence in Indonesia's "Sekolah Penggerak"

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ABSTRACT

This research examines the impact of the "Platform Merdeka Mengajar" on elementary school teachers in Indonesia, focusing on its role as a catalyst for enhancing educational quality in the "Program Sekolah Penggerak". This study adopts a qualitative case study method, involving one hundred elementary school teachers and one hundred students participating in the programme. Key informants include twenty-five facilitators, representatives from "Balai Besar Guru Penggerak", "Balai Penjaminan Mutu Pendidikan", and other educational practitioners. Data were collected through observation, interviews, and documentation, and validity was ensured using data triangulation. The analysis followed Stake's stages, including categorical aggregation, direct interpretation, pattern recognition, and naturalistic generalisations. Findings reveal that the "Platform Merdeka Mengajar" offers various features for teachers, such as inspirational videos, independent training, real action tools, proof of work, class creation options, teaching resources, and student assessment tools. These features enhance teacher competence, enabling effective knowledge transfer, and helping achieve measurable learning goals. The platform also facilitates student assessment, providing insights into learning outcomes. Accessible on Android, the platform proves to be both effective and efficient. The level of success depends on teacher engagement with the paltform's features, making it a valuable tool in achieving educational objectives within the "Program Sekolah Penggerak."

Keywords: Catalyst, educational quality, elementary school teacher, *Platform Merdeka Mengajar*, *Program Sekolah Penggerak*

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INTRODUCTION

Background of the Study

Education in Indonesia began during the Dutch East Indies and Japanese rule (Suratno, 2011). After independence, the education curriculum in Indonesia underwent 12 changes (Batubara & Davala, 2023; Oktavia et al, 2023). Curriculum changes in Indonesia were carried out to improve the quality of education and the quality of Indonesian society (Jannah, 2023; Pakpahan et al., 2023). Curriculum changes cannot be separated from changes in eras of leadership and political turmoil in the country (Lubis et al., 2022; Sakhiyya & Rahmawati, 2024). Until now, several challenges in achieving this quality of education are still faced by the Indonesian nation. Referring to data from the Central Statistics Agency in 2022, one third of the entire Indonesian population aged over five years has a junior high school education level. Another fact shows that college graduates in Indonesia are only 7.57% Indonesia's Development Index achievement in 2023 is still at 0.71 and is ranked 112th in the world. Indonesia's Programme for International Student Assessment score is still below the average for the Organisation for Economic Cooperation and Development and ASEAN-5 (Litbang Kompas).

Various things have been done to overcome these challenges, one of which is to make a breakthrough in educational innovation by launching the "Program Sekolah Penggerak", which was carried out on February 1, 2021, by the Ministry of Education and Culture, Research and Technology of the Republic of Indonesia. The "Program Sekolah Penggerak" is an effort to realise the vision of advanced Indonesian education that is sovereign, independent, and has personality through the "Profil Pancasila Student". Schools that are members of the "Program Sekolah Penggerak" implement the "Kurikulum Merdeka" in their learning. To implement the "Kurikulum Merdeka", the Indonesian government launched the "Platform Merdeka Mengajar" to help teachers get references, inspiration and understanding of the "Kurikulum Merdeka" (Inspektorat Jenderal Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi [Itjen Kemendikbudristek], 2023).

Many studies have been conducted on the use of the "Platform Merdeka Mengajar", including research conducted by Rahmadani and Kamaludin (2023), which showed that the use of the "Platform Merdeka Mengajar" significantly improved teacher competence in vocational schools. The "Platform Merdeka Mengajar" provides better access to educational resources, training, and collaboration between teachers. Teachers can also share experiences and best practices and gain access to the latest learning materials. In addition, the "Platform Merdeka Mengajar" allows teachers to improve their ability to teach vocational techniques. This research makes an important contribution to the development of education in vocational schools, especially in the use of technology and online platforms to improve teacher skills. The benefits of the "Platform Merdeka Mengajar" felt by 90.3% of PPKn teachers at SMP Negeri throughout

Sijunjung Regency were gaining inspiration, references and a deep understanding of the nature and implementation of the "Kurikulum Merdeka". Teachers are motivated to continue learning, teaching, and working through the ecosystem built on the "Platform Merdeka Mengajar."

In contrast to these studies, this research examines the impact of the "Platform Merdeka Mengajar" on elementary school teachers in Indonesia, focusing on its role as a catalyst for enhacing educational quality in the "Program Sekolah Penggerak."

Statement of Problems

Although the Indonesian education curriculum has undergone various changes in an effort to improve quality, a number of fundamental problems remain, such as low educational attainment, disparities in teacher quality, and substandard international assessment results. To address these issues, the government launched the "Program Sekolah Penggerak", implementing the "Kurikulum Merdeka", supported by the "Platform Merdeka Mengajar". However, studies on the use of this platform by elementary school teachers, particularly in the context of the "Program Sekolah Penggerak", are still limited. Therefore, an in-depth analysis is needed to examine the extent to which the "Platform Merdeka Mengajar" can act as a catalyst in improving the quality of basic education in Indonesia.

Research Objectives

The following are the problem formulations that will be discussed in depth in this paper: (1) What is the "Platform Merdeka Mengajar?"; (2) What are the features available on the platform? (3) What are the advantages of utilising the platform for elementary school teachers? and (4) How can the platform be a catalyst for improving the quality of education in the "Program Sekolah Penggerak?"

Significance of Study

The importance of this research is its contribution to addressing the challenge of improving the quality of basic education in Indonesia. Elementary school teachers are at the forefront of shaping the quality of learning, so strengthening their competencies through the use of educational technology is highly strategic. The " Platform Merdeka Mengajar" presents itself as an innovation that offers learning resources, independent training, collaboration, and learning inspiration, but its use at the elementary school level has not been comprehensively studied. This research is important because it can provide a deeper understanding of how the platform is optimized to empower teachers, strengthen the implementation of the "Kurikulum Merdeka", and become a catalyst for the success of the "Program Sekolah Penggerak" towards realising quality and globally competitive Indonesian education.

LITERATURE REVIEW

"Program Sekolah Penggerak"

The Ministry of Education, Culture, Research and Technology of the Republic

of Indonesia (https://sekolah.penggerak.kemdikbud.go.id/ stated that the "Program Sekolah Penggerak" is an effort to realise the vision of Indonesian Education in realising a sovereign, independent, and personality-based advanced Indonesia through the "Profil Pelajar Pancasila" Students. The "Program Sekolah Penggerak" focuses on developing student learning outcomes holistically, which includes competencies (literacy and numeracy) and character, starting with superior human resources (principals and teachers). The "Program Sekolah Penggerak" is a refinement of the previous school transformation program. The "Program Sekolah Penggerak" will accelerate public/private schools in all school conditions to move 1-2 stages more advanced. The programme is carried out in stages and integrated with the ecosystem until all schools in Indonesia become "Program Sekolah Penggerak."

There are five characteristics of the "Program Sekolah Penggerak", namely: (1) A collaborative programme between the Ministry of Education and Culture and the Regional Government where the commitment of the Regional Government is the main key, (2) has a scope and covers all school conditions, not only superior schools, both public and private, (3) the programme is integrated with the ecosystem until all schools in Indonesia become "Sekolah Penggerak", (4) interventions are carried out in a holistic, starting from school human resources, learning, planning, digitalisation and assistance from the Rgional Government and (5) assistance is carried out for 3 academic years and the school continues its transformation efforts independently.

The five interventions of the "Program Sekolah Penggerak" include: (1) Consultative and asymmetric assistance; (2) Strengthening human resources in schools; (3) Learning with a new paradigm; (4) Data-based planning; (5) School digitalisation.

"Platform Merdeka Mengajar"

The "Platform Merdeka Mengajar", according to the Ministry of Education, Culture, Research and Technology of the Republic of Indonesia, was built to support the Implementation of the "Kurikulum Merdeka" so that it can help teachers get references, inspiration, and understanding of the "Kurikulum Merdeka" (Itjen Kemendikbudristek, 2023). This platform is also provided to be a driving companion for teachers and principals in teaching, learning, and working. The "Platform Merdeka Mengajar" can be accessed via the Android and Chromebook applications.

Wardana et al. (2023) stated that, in general, the "Platform Merdeka Mengajar" application is considered easy to install by users, this means that this application has succeeded in providing a smooth experience for users. In addition, the use of this application is also beneficial in terms of time flexibility, users can access the "Platform Merdeka Mengajar" from anywhere and anytime if they are connected to the internet.

The "Platform Merdeka Mengajar" has the following features: (1) A learning

platform that balances technological and human touch; (2) A learning platform that improves competence, character, and spirituality; (3) The human focus feature is used in conjunction with the technology platform; (4) The platform targets the Indonesian nation, which has a super smart society with big data.

"Kurikulum Merdeka"

The "Kurikulum Merdeka" is a curriculum with diverse intracurricular learning where the content will be more optimal so that students have enough time to explore concepts and strengthen competencies. Teachers have the freedom to choose various teaching tools so that learning can be adjusted to the learning needs and interests of students. The "Kurikulum Merdeka" provides educators with the freedom to create quality learning that is in accordance with the needs and learning environment of students (Itjen Kemendikbudristek, 2023). The "Kurikulum Merdeka" is an effort to recover from the learning crisis and improve the quality of education carried out by the Indonesian Government. Facts on the ground show that the "Kurikulum Merdeka" is effective in efforts to utilise technology and learning communities to share good practices between teachers, students and academics (Fitra, 2023; Nugraha, 2022).

The Ministry of Education, Culture, Research and Technology provides six supports in implementing the "Kurikulum Merdeka", namely the "Platform Merdeka Mengajar","Komunitas Belajar","Narasumber Berbagi Praktik Baik","Seri Webinar","Mitra Pembangunan", and "Pusat Layanan Bantuan" (Itjen Kemendikbudristek, 2023).

The "Kurikulum Merdeka" is based on constructivism theory, which emphasises that knowledge is actively constructed through interaction with the environment (Piaget, 1972; Vygotsky, 1978). Furthermore, the humanism theory developed by Rogers and Carl (1969) and Maslow (1970) serves as an important foundation, positioning students as unique, free individuals with a need for self-actualisation. Furthermore, the connectivism theory introduced by Siemens (2005) and Downes (2008) also provides a foundation for utilising digital technology and networks as learning resources that enable students to build knowledge collaboratively. Based on these theories, the "Kurikulum Merdeka" is designed to improve the quality of education in Indonesia in a holistic and integrative manner.

Human Resources for Elementary School Teachers

The most important resource to ensure the success of the teaching and learning process and improve education standards is the teacher. Because the success or failure of their students depends on a number of factors, including the way the teacher teaches, instructors are expected to behave professionally when teaching or educating their students. The effectiveness of the teaching and learning process determines the standard of student learning, and the position and function of teachers in this process are very influential (Manora et al., 2024).

The role of teachers in the implementation of independent learning is as driving teachers, innovative teachers, learning facilitators, characteristic teachers, and creative and independent teachers. Improving teacher resources is carried out through training and then providing compensation and allowances. One of the ministry's programmes, which of course is also a programme of the education office, is "Program Kurikulum Merdeka", and there is also "Platform Merdeka Mengajar", where there are many learning media that can be downloaded or viewed by all teachers and there are also stages.

Quality of Education in Indonesia

The quality of education is the ability of educational institutions to utilise educational resources to improve learning abilities as optimally as possible. In terms of education, the meaning of quality refers to the process of implementing education and its educational outcomes (Kurniawati, 2022; Larasati, 2022).

According to PISA 2018, Indonesia is internationally ranked 72 out of 79 countries that are members of the Organisation for Economic Co-Operation and Development (OECD, 2018) and in the TIMSS 2015 results, Indonesia ranked 44 out of 49 countries for mathematics and ranked 44 out of 47 countries in the field of arts. Based on these data, it is clear that the low achievement of students in the quality of Indonesian education is low, so the role of competent teachers is still very much needed and still needs to be improved as research by UNESCO Global Education Monitoring (GEM) Report 2016, where Indonesia's quality is ranked fifth from the bottom of 14 other developing countries regarding the quality of education. However, based on the latest research, the UNESCO Global Education Monitoring (GEM) Report 2020 stated that the quality of education throughout the world has declined due to a lack of finances so that many students have dropped out of school due to the Covid-19 pandemic. (Adamson et al., 2021). The quality of education is said to be good if it has good input and output values, meaning that these values can later solve problems in society. The quality of education in Indonesia is still very low compared to other countries in the Southeast Asian region. However, the government continues to strive to provide improvements in the quality of education for the community to create superior human resources so that they can compete with the outside community (Wahyudi et al., 2022).

METHODOLOGY

Research Design

This study uses a qualitative research method that is a case study. Case study research is a type of qualitative approach whose research explores the real life of a case or various cases through in-depth data collection.

This study examines casuistically;

1. What is the "Platform Merdeka Mengajar?"
2. What are the features available on the platform?

3. What are the advantages of using the platform for elementary school teachers?
4. How can the platform be a catalyst for improving the quality of education in the "Program Sekolah Penggerak?"

Participants

Participants in this study consisted of several parties who were directly involved and experienced the events studied. In this case, the participants are one hundred elementary school teachers and one hundred students participating in the programme. Key informants include twenty-five facilitators, representatives from "Balai Besar Guru Penggerak", "Balai Penjaminan Mutu Pendidikan", and other educational practitioners.

Instruments and Data Collection Techniques

The research instrument is basically a tool used to collect data from research. In the research, the instrument used was a semi-open questionnaire distributed to participants and informants. Data collection techniques used were observation, interviews, and documentation. The aspects observed were (1) the "Platform Merdeka Mengajar "and its various features, (2) teacher skills in utilising the "Platform Merdeka Mengajar", (3) learning using the "Platform Merdeka Mengajar", (4) student responses in learning when teachers use the "Platform Merdeka Mengajar". Interviews were conducted using in-depth interviews and focus group discussions. Meanwhile, documentation includes data on elementary schools that are members of the "Program Sekolah Penggerak" in Central Java and East Java Provinces, data on teachers who are members of the "Program Sekolah Penggerak" in Central Java and East Java Provinces, the "Platform Merdeka Mengajar", and other data related to the focus of this research.

Data Validity Technique

The validity of the data in this study uses data triangulation techniques, namely comparing data from observations, interviews and documentation, comparing what people say individually and what they say in public; and comparing secondary data. If the data has similarities, it means the data is declared valid, but if the data is different, it is not immediately discarded, because there is a possibility that the data will become found data.

Data Analysis Technique

Data analysis techniques use the Stake stage, including categorical aggregation, direct interpretation, establishing patterns and looking for a correspondence between two or more categories and naturalistic generalisations.

RESULTS

"Platform Merdeka Mengajar"

Questionnaire questions regarding the "Platform Merdeka Mengajar" include:

1. Do you know what the "Platform Merdeka Mengajar" is?
2. How did you learn about the "Platform Merdeka Mengajar?"

3. How do you use the "Platform Merdeka Mengajar?"
4. Do you often use the "Platform Merdeka Mengajar?" How often?

A questionnaire regarding teachers' understanding of the "Platform Merdeka Mengajar" concept was given to teachers, principals and facilitators who members of the "Platform Merdeka Mengajar" are. The results of the questionnaire stated that most teachers did not know what the "Platform Merdeka Mengajar" was conceptual. So far, if they want to use the "Platform Merdeka Mengajar", teachers only need to access it via the Android or Chromebook application. Figure 1 presents the results of the questionnaire regarding this matter.

Meanwhile, Figure 2 presents the frequency with which the teachers use the "Platform Merdeka Mengajar."

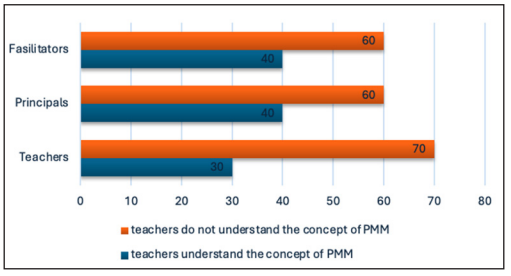

Figure 1. Teacher understanding of the "Platform Merdeka Mengajar" concept

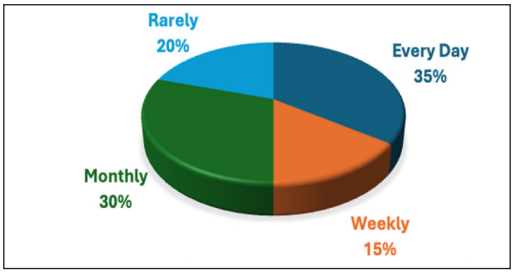

Figure 2. "Platform Merdeka Mengajar" utilisation percentage

Features in "Platform Merdeka Mengajar"

Questionnaire questions regarding the features available on the Platform "Merdeka Mengajar Platform," including:

1. How many features are there on the Platform Merdeka Mengajar?
2. What are the features available on the Platform Merdeka Mengajar?
3. Do you know what the features are?
4. Have you ever used all the features available on the Platform Merdeka Mengajar?
5. Which features do you visit most often?
6. Which features do you rarely visit?
7. Are there any obstacles in using the Platform Merdeka Mengajar?
8. How do you overcome these obstacles?

The results of the documentation regarding the Platform Merdeka Mengajar are presented in Figures 3, 4, and 5.



Figure 3. "Platform Merdeka Mengajar" initial view



Figure 4. "Platform Merdeka Mengajar" features

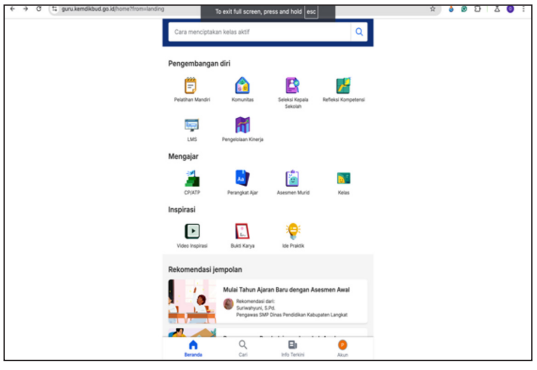

Figure 5. "Platform Merdeka Mengajar" features

Benefits of Using the "Platform Merdeka Mengajar" for Elementary School Teachers

The questionnaire on the benefits of using the "Platform Merdeka Mengajar" for elementary school teachers includes:

1. What are the advantages of the "Platform Merdeka Mengajar?"
2. What are the benefits of using the "Platform Merdeka Mengajar?"

The questionnaire was given to participants and informants. Here are their answers:

> ...There are many advantages, from the many features, the content, the appearance, the convenience, the benefits... (P78)

> ...The benefits are that it increases teaching inspiration, my competence increases, I have lots of ideas in class, classes become more fun, I can save documents online, teaching becomes easier, there is a P5 concept... (P90)

"Platform Merdeka Mengajar" as a Catalyst for Improving the Quality of Education in the "Program Sekolah Penggerak"

The "Platform Merdeka Mengajar" questionnaire as a catalyst for improving the quality of education in the "Program Sekolah Penggerak" contains:

1. What is the role of the "Platform Merdeka Mengajar" for you?
2. Will you continue to use the "Platform Merdeka Mengajar?" Why?
3. Do you think the "Platform Merdeka Mengajar" can improve the quality of education? Why?
4. What are your suggestions and input related to this!

This questionnaire was given to the teachers. Figure 6 presents one of the teacher's answers to Question No. 4.

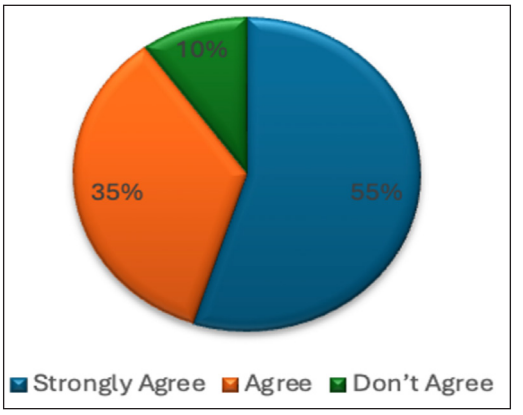

Figure 6. Platform Merdeka Mengajar can improve the quality of education

DISCUSSION

"Platform Merdeka Mengajar"

The "Platform Merdeka Mengajar" is one of the supporting media in the implementation of the "Kurikulum Merdeka" used by schools, especially schools that are members of the "Program Sekolah Penggerak", as stated by the Ministry of Education, Culture, Research and Technology (Itjen Kemendikbudristek, 2023). Based on the results of the study, 70% of teachers stated that they did not know the concept of the "Platform Merdeka Mengajar", while the principal and facilitator stated 60%. It was further stated that teachers have so far used

the "Platform Merdeka Mengajar" directly by browsing the internet. Even though teachers do not understand the concept of the "Platform Merdeka Mengajar", they still use the platform in their daily lives. This is due to the ease of accessing the platform. As stated by Wardana et al. (2023), the "Platform Merdeka Mengajar" application is easy to install and flexible to use anywhere and anytime. This is also reinforced by the results of research presented by Istiqomah, et al. (2024) that most teachers find it easy to access the "Platform Merdeka Mengajar", indicating a user-friendly platform design. These data are sufficient to strengthen the positive perception of the existence of the "Platform Merdeka Mengajar". Meanwhile, the intensity of teachers in using the "Platform Merdeka Mengajar" is 35% stating every day, 15% stating weekly, 30% stating monthly and 20% stating rarely using it. Differences in the intensity of teachers in using the platform are influenced by individual instructional desires, instructional needs, and different levels of technological capabilities.

"Platform Merdeka Mengajar" Features

The results of the study show that the "Platform Merdeka Mengajar" features are very diverse. The "Platform Merdeka Mengajar" has many diverse features that can be accessed by teachers freely with or without logging in to the application, each of which has different information. The results of the documentation regarding the "Platform Merdeka Mengajar" show that "Platform Merdeka Mengajar" features that can be opened without logging in are "Informasi Terkini", "Setting", and "Video Inspirasional". Meanwhile, features that can be explored by logging in are "Pengembangan Diri" (Pelatihan Mandiri, Komunitas, Seleksi Kepala Sekolah, Refleksi Kompetensi, LMS, Pengelolaan Kinerja), "Mengajar" (CP/ATP, Perangkat Ajar, Asesmen Murid, Kelas), "Inspirasi" (Video Inspirasi, Bukti Karya, Ide Praktik), "Rekomendasi Jempolan" dan "Dokumen Rujukan."

There are several features that are frequently accessed by teachers, such as "Kurikulum Merdeka", "Asesmen Siswa", "Perangkat Ajar", "Pembinaan Mandiri", "Komunitas", "Video Menginspirasi" and "Bukti Karya". These features are frequently accessed due to the high demand from teachers for the materials presented.

Many other studies have shown varying results on the level of intensity of access to features in the "Platform Merdeka Mengajar", such as research by Triningsih et al. (2024) which shows that the feature that is often accessed by teachers is "Asesmen Siswa" because it makes it easier for teachers to analyze learning and map student abilities so that they can be reused for further learning planning. Ambawani et al (2024) said that the feature that is often accessed is "Aksi Nyata" because it can obtain independent training certificates that can be used for teacher performance management assessments. Rohman et al. (2024) said that the feature that is often accessed by teachers is "Pengembangan Diri" because it provides many diverse activities that can improve teacher competence.

Benefits of Using the "Platform Merdeka Mengajar" for Elementary School Teachers

Learning for students in Elementary School is different from learning for students at other levels; this is due to the differences in the characteristics of Elementary School students and students at the next level. These differences in characteristics cause differences in the treatment of learning delivered by teachers; teachers must use various models, methods, and media that can meet students' learning needs according to their learning phase. For this reason, teachers must be creative and innovative in using learning models, methods, and media. The results of the study show that with the "Platform Merdeka Mengajar", teachers can access many things that can improve the quality of their learning.

Some of the advantages of using the "Platform Merdeka Mengajar" for Elementary School teachers are:

1. Increase teaching inspiration for teachers. Through various features for work, teachers can share various experiences in creating quality learning. By seeing and observing some of the experiences shared in these features, it can be an inspiration for teachers to refer to and modify the learning that will be carried out.
2. Improve teacher competence. The "Platform Merdeka Mengajar" presents various types of training that can be followed by teachers independently whenever and wherever they are. This freedom of access can increase the intensity of training followed by teachers so that there is a lot of new information that can improve teacher competence.
3. Enriching teachers' ideas and creativity while in class. Various features provided, especially related to sharing learning videos, will enrich teachers' ideas and creativity in developing activities in the classroom.
4. Making learning meaningful and enjoyable.
5. Storing documents online. Several documents accessed by teachers in the application can be easily stored online.
6. Making it easier for teachers to teach. The "Platform Merdeka Mengajar" can also be used as teaching materials; teachers can easily teach according to student assessments and diagnostic literacy analysis.
7. Bringing up the concept of the "Profil Pelajar Pancasila". In the "Platform Merdeka Mengajar", the "Profil Pelajar Pancasila" is a character that is included in learning as a real action.

These advantages are also supported by other studies such as research by Marisana et al. (2023), Rahmadani & Kamaluddin (2023), Setiariny (2023), and Wardana et al. (2023).

"Platform Merdeka Mengajar" as a Catalyst for Improving the Quality of Education in the Program Sekolah Penggerak

Schools that are members of the "Program Sekolah Penggerak" are required to implement the "Kurikulum Merdeka."

One of the tools and supporters of the implementation of the "Kurikulum Merdeka" in schools is the use of the "Platform Merdeka Mengajar", as per the policy of the Ministry of Education, Culture, Research and Technology of the Government of the Republic of Indonesia which states that there are six supports in implementing the "Kurikulum Merdeka", namely the "Platform Merdeka Mengajar", "Komunitas Belajar", "Narasumber Berbagi Praktik Baik", "Seri Webinar", "Mitra Pembangunan", dan "Pusat Layanan Bantuan" (Itjen Kemendikbudristek, 2023).

The results of the study, based on one of the questionnaire questions asked to teachers, showed that 55% of teachers strongly agreed that the "Platform Merdeka Mengajar" could be a catalyst for improving the quality of education. Meanwhile, 35% agreed and 10% disagreed. Based on further questions, data was obtained that teachers who strongly agreed and agreed were teachers who had made extensive use of the "Platform Merdeka Mengajar". Teachers who disagreed were teachers who had not yet utilised the "Platform Merdeka Mengajar". Teachers were greatly helped by the various information and activities in the "Platform Merdeka Mengajar" because they could provide benefits both internally and externally. Internally, there is an increase in self-competence and externally, there is an increase in the quality of learning carried out. Improving self-quality and learning quality is very important in efforts to improve the quality of education in Indonesia because teachers are the spearhead of education implementation in schools. Teachers are one of the most influential factors in the success of education. As conveyed by Indartiningsih (2023) and Nurjanah et al. (2023).

Data from the Ministry of Education, Culture, Research and Technology in 2022 stated that the "Platform Merdeka Mengajar" has helped 1.8 million people continue learning, teach better and create work. It was further conveyed that not only teachers in big cities or regions with adequate network infrastructure, but teachers in 3T ("Tertinggal, Terdepan dan Terluar") areas have also utilised the "Platform Merdeka Mengajar". In 3T areas, there are already 100 thousand activated belajar.id accounts, 29 thousand teacher users have accessed the "Platform Merdeka Mengajar", and 20 thousand teachers are actively using the five main menus on the "Platform Merdeka Mengajar". Another achievement is that in 2022, there were 80 thousand works uploaded by more than 30 thousand teachers from various provinces. This is positive evidence that the spirit of "Merdeka Belajar" has truly become a contagious movement and has had a positive impact in various regions in Indonesia.

Based on the above explanation, the "Platform Merdeka Mengajar" launched by the Ministry of Education, Culture, Research and Technology of the Government of the Republic of Indonesia has proven to be a catalyst for improving the quality of education in Indonesia, especially in schools that are members of the "Program Sekolah Penggerak" and for all schools in general.

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How Do Elementary Student's Critical Thinking Taught by STEM-PjBL in Science Thematic Learning?

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ABSTRACT

One of the best ways to develop students' critical thinking abilities is to incorporate STEM (Science, Technology, Engineering, and Mathematics) disciplines with Project-Based Learning (PjBL). This study emphasises the originality of integrating STEM with PjBL to explicitly improve critical thinking inside thematic learning environments, even though PjBL is recognised to aid cognitive development and problem-solving. This study examined the effects of STEM-PjBL on elementary students' critical thinking during science-themed learning. The study sought to demonstrate how STEM-PjBL, as opposed to regular PjBL, promotes deeper critical thought, analysis, and problem-solving, building earlier findings. 24 fifth-grade students from SDI Surya Buana Malang participated in the study, which used a pre-experimental design with a one-group pre-test-post-test methodology. Five essay questions that were verified by specialists and proved to be reliable (Cronbach's alpha = 0.805) were used to evaluate the students' critical thinking abilities. The results show that, in this particular setting, students' critical thinking abilities significantly improved after the STEM-PjBL intervention. These results indicate the model's potential for broader educational applications beyond cognitive benefits and show how well it can foster critical 21st-century abilities. Future studies could examine how this paradigm affects abilities other than critical thinking.

Keywords: Critical thinking, Project-Based Learning, STEM, thematic science

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INTRODUCTION

Teachers have to be in a position to work out learning models that can enhance the aspect of critical thinking. Today, a teacher is not only the informant of knowledge and facts but also the key who unlocks the thinking

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abilities of the learners (Kusmahardhika, 2023). Recent approaches that comprise Project-Based Learning (PjBL) have been validated to enhance student's critical thinking levels (Martawijaya, 2023; Sumarni, 2023). Several studies prove PjBL enhances students' content knowledge, engages them in more thoughtful processing of information, and promotes the production of extended and more sophisticated analyses of the content matter and more thorough evaluation of the put content (Agustina, 2023).

The Engaging project-based learning (PJBL) model leads to an uplift in students' critical thinking. As applied to the current curriculum, this model demands the participation of students through projects that are work-like and real life like (Mustikasari, 2020). Information is introduced to learners in the PJBL model, and they have to look for the information on their own and also they have to classify and interpret the information so as to make the results of the given project (Lainufar, 2021). It entails a range of skills involving comprehension and evaluation of information that include problem analysis, distributing information, and making decisions on the basis of presented data. Students need to schedule and execute their projects, and switch among them; this involves analysis and self-reflection. Moreover, project-based learning will include students' collaboration, where the latter will have to negotiate, share information, and make decisions, which are all the elements of critical thinking (Tresnawati, 2021; Yusuf, 2023).

Hence, the existence of thematic science learning becomes a problem studied within the context of this research at Islamic Elementary School Surya Buana Malang. A good number of teachers at that school keep applying the traditional model, which is connected to the scientific method. Apparently, the learning media (PowerPoint slides) has not enhanced students' critical thinking skills. The necessity of training and implementing more mentors for the teachers on innovative learning models altogether affects the teaching process. The problem needs to be tackled as soon as possible to prevent it from aggravating.

Although traditional science learning in elementary schools has implemented the scientific method, we found that this approach often fails to foster critical thinking skills because it can become overly procedural (Etherington, 2011; Rusmin et al., 2024). In our research, we contend that this restriction is strengthened by the "cookbook" approach, which limits students to preset procedures meant to produce a specific outcome, hence decreasing interaction in real-world problem-solving. (Khumraksa & Burachat, 2022; Shana & Abulibdeh, 2020). We found that an emphasis on procedures tends to prioritise memorisation and manual dexterity over higher-order cognitive processes such as analysis, evaluation, and inference (Barsoum et al., 2022; Rusmin et al., 2024). Notably, Arango-Caro et al. (2025) and Breukelen et al. (2015) stated that thematic learning that does not integrate interdisciplinarity will make it difficult for students to understand scientific concepts and connect contextual phenomena.

Several previous studies have implemented STEM-PjBL at various levels of education (Pramasdyahsari et al., 2023; Rahmawati, 2021), but still limited studies which examine the effect of STEM-PjBL in thematic learning at the elementary school level. On top of that, this study emphasises the novelty of its research lies in the integration of STEM PjBL in thematic science learning, which is expected to encourage students' critical thinking and problem-solving skills (Mulyani & Arif, 2021). This study also examines how the model is applied in the local context, related to teacher readiness and other resources (Khaerunisa, 2024; Solihin, 2021). Several previous studies have focused more on the implementation of the STEM-PjBL Model in high schools or higher education, as well as in single subjects (Farwati et al., 2021; Khotimah, 2021; Nugraha et al., 2017; Syaifuddin et al., 2025). However, this study investigates the application of STEM - PjBL in the context of thematic learning, with an integrated curriculum for 5th grade elementary school students. The fundamental difference lies in how interdisciplinary STEM components can be integrated into the thematic learning framework in Indonesia, without losing the essence of its basic science concepts.

Strengthening PjBL through STEM alignment is crucial for addressing 21 century learning challenges, most notably in boosting students' critical thinking capabilities (Beier, 2019; Edmunds, 2017). PjBL through STEM alignment make students capable of engaging the knowledge they get from their class work into real-life situation analysis, problem-solving and most at times creativity (Ashari, 2021; Rahmawati et al., 2021). Nonetheless, there are few issues that have to be resolved to effectiveness of STEM-PjBL which includes teacher's resistance to innovation (Khaerunisa, 2024b; Sumarni, 2023a). This is particularly the case so that many teachers may feel at ease with this traditional system of education and may not venture to apply methods they are not fully capable of handling. Furthermore, he reported that implementing STEM-PjBL entails deeper readiness in the realm of project designing (Admawati, 2021), resource support (Solihin, 2021), and formative assessment (Samsudin, 2020). Teachers need to have content knowledge of STEM and incorporate it into student appropriate and meaningful projects.

However, it focuses on how the adoption of the STEM-PjBL model impacts thematic science learning in the context of SDI Surya Buana. STEM-PjBL stands for project learning based on combining four major subject fields in one. It involves students, makes learning more productive and effective, and fosters 21st century learner Competency skills such as problem solving and collaboration. The thematic science implementation within the curriculum focuses on explaining scientific concepts in the context of students' daily lives, aiming to increase the depth and applicability of their knowledge.

In addition, it also seeks to understand how the implementation of the STEM-PjBL

model influences students' motivational interest in science learning. This research can supply useful suggestions for educators and educational policymakers in designing and evaluating effective and creative types of learning programs by studying these aspects. Hence, this study also adds value to the teaching learning process of SDI Surya Buana and also may serve as contextual reference for other institutions wishing to embrace similar learning approaches.

The possibility of deploying STEM-PjBL in other contents or at other school levels is expected to be evaluated for its feasibility (Vidic, 2022). Here, the application of the STEM-PjBL model has significance in enhancing students' critical thinking abilities in the STEM area, and it can effectively be used in a variety of subjects and other grades as well.

Basing on the achievements of using project-based learning methods with the STEM approach can offer so maturity and educational integration where both sites are invited to apply concepts of many fields at the same Time in the project application. Another aspect is the quantitative validation of the newly developed STEM-PjBL model at different levels and contents, as well as to determine which strategies of this approach are the most effective, and how this approach can be integrated into the curriculum (Widiyanto, 2021). Strong empirical evidence for expanding the application of the STEM-PjBL model could be provided by additional research on student learning outcome, motivation, and engagement (Fatin, 2023; Rustaman, 2020). Thus, exploring and testing the STEM-PjBL model in various educational contexts is expected to produce more innovative, effective, and relevant learning approaches to prepare students for future challenges.

LITERATURE REVIEW

Project-Based Learning Integrated STEM

According to (Ertmer & Glazewski, (2019); Krajcik et al., (2022), project-based learning is an approach to education that involves students in continuous projects to solve real-world problems. Additionally, STEM education emphasises the integration of several academic fields, such as science, technology, engineering, and mathematics (Cheng & So, 2020). STEM-PjBL, which combines these two teaching strategies, promotes more difficult and contextual inquiry learning (Amelink et al., 2024; Chang & Yen, 2023; Krajcik et al., 2022). Fostering 21st-century skills like creativity, teamwork, critical thinking, and problem-solving abilities requires this integration (Krajcik et al., 2022).

According to Krajcik et al. (2022), the primary elements of STEM-PjBL are posing thought-provoking questions and providing step-by-step assistance. According to Krajcik et al. (2022), the main way to promote continuous inquiry, assist students in identifying issues and coming up with solutions, and guarantee consistency throughout project activities is to pose provocative questions (Fitzgerald & Evans, 2024; Krajcik et al., 2022). Prompting questions, such as "How can we conserve

birds in our environment?" relate to common natural phenomena that elementary school pupils encounter. By describing phenomena, conducting research, and creating models, this can inspire students to participate in scientific activities (Fitzgerald & Evans, 2024; Krajcik et al., 2022). To encourage curiosity and the creation of new knowledge, the questions must be relevant, contextual, and helpful (Krajcik et al., 2022).

Hmelo-Silver (2004) has studied dynamic scaffolding, using tutors, tools, prompts, or technology, that can help students with challenging assignments that are beyond their capabilities, progressively reducing as their abilities advance (Ertmer & Glazewski, 2019; Hmelo-Silver, 2004). Scaffolding in inquiry processes can promote engagement, sustain motivation, clear up misunderstandings, and promote reflection in the classroom in elementary education (Ertmer & Simons, 2006). Collaborative roles, cognitive tools, and question prompts are some examples of this type of scaffolding. In PjBL, scaffolding can facilitate self-directed learning and transmit the learning process in real time (Hmelo-Silver et al., 2009).

Laboy-Rush (2011), believes that the STEM-PjBL architecture has five critical steps that assist pupils learn in diverse topics. First step, students analyse their prior understanding counter to contextual real-world phenomenon to define the scope of their inquiry, in an Initial Reflection Phase. Subsequently, the research stages emphasise students to collect data in a rigorous way, combining scientific literature and real-world examples. The following step, students examine their ideas, employing the scientific and technical method, in Discovery Stage. This leads to the Application stage; students are given problems to solve by making models or prototypes address real-world issues. Finally, communication stages serve as a reflective platform, where students present their findings to an external audience while articulating their methodology and insights. The holistic approach bridging the gap between classroom theory and real-word utility, thereby enhancing students' critical thinking and collaborative abilities in a professional context.

Afriana et al. (2016), Dewi (2020) and Han et al. (2015) stated that STEM-PjBL potentially improve students figure out problems and judging their own work. On top of that, students' creativity skills accelerating (Hanif et al., 2019), because students' used to think critically and develop innovative solutions to problems than those who learn conventionally (AlAli, 2024). Aside from that, students get fascinating in STEM-based lesson and get more involved in their studies (LaForce et al., 2017; Tseng, 2012).

Luo et al. (2024) also found that the STEM-PjBL learning process can get students more interested in learning and make them want to learn more. This is because the STEM-PjBL model of learning makes students do project work that makes them think about things in a scientific and contextual way (Pramasdyahsari et al., 2023). In this way, the method engages students in activities where they do something with

real materials that are brought from life and not only imagined as a whole classroom. Additionally, STEM - PjBL supports team working through its structure for teams' collaborative activities (Bulu & Tanggur, 2021). What is more, learners may face real challenges and look for creative solutions which enhance their self-esteem and performance (Mulyani & Arif, 2021). Therefore, academic comprehension improves through STEM - PjBL leading to better readiness of the learners for future STEM careers. In general, STEM-PjBL is a holistic and effective approach to enhancing students' 21st-century skills (Baran et al., 2021; Rahmania, 2021). These methods boost concept comprehension via reflection, examination, invention, practicality, and transmission. It nurtures vital traits required to overcome a complex world ever increasing in technological advancement.

Critical Thinking

Critical thinking skills are among the most essential cognitive competences within educational processes specifically in the context of 21st-century education that requires learners to not only acquire knowledge but also be capable of analysing, evaluating and generating solutions to intricate problems. Critical thinking refers to clear and rational reasoning about what to believe or do (Heard et al., 2020). On the other hand, according to Akpur (2020), critical thinking involves reflective systematic and evaluative thinking concerned with deciding on what one ought to do or believe.

Critical thinking is not one type of skill, but a combination of many components which interact. Facione (2011) lists six major components of critical thinking: make sense of, examination, evaluation, conclusion, elaboration, and self-management. Make sense of involvement in knowing or expressing the meaning or importance of various experiences, situations, data statements and events. Examination entails scrutinising concepts; explaining arguments; and examining connections between statements or ideas. Evaluation implies assessing the truth of worthiness of statements or the adequacy of justifications. Inference is concerned with drawing conclusions from already stated information. Explanation refers to being able to state and justify what has been produced by one's thought while self-regulation refers to monitoring and adjusting one's own thinking approach.

There's no doubt that critical thinking skills are instrumental in student learning, especially facing the challenge of globalisation and information complexity era (Halpern, 1998). These skills foster the high-level thinking needed by students to solve problems, make good decisions, and learn independently through life. According to Finn (2011), critical thinking enables learners to express different views, differentiate between facts and opinions, and create logical as well as evidence-based perspectives. Moreover, critical thinking abilities constitute also meaningful and

transformative learning since they enable learners to relate their knowledge with new contexts and gain a better grasp of what is taught.

Although important, there are a number of challenges in the development of critical thinking abilities among students. One of the primary ones is that traditional approaches to learning lean too much on memorising and expanding information instead of understanding it deeply as well as critical thinking. Furthermore, not all teachers have a deep understanding about how to impart these skills efficiently. As a result; this prevents learners from developing critical thinking abilities necessary for them to thrive in today's complex world (Willingham, 2007). For instance, according to El Soufi and See (2019), explicit teaching on the subject matter is needed so as to enable pupils perfect for such expertise. However, several schools have not yet embraced such ways of teaching uniformity.

Critical thinking skills have been proposed and implemented through various strategies among students. A prevalent instructional strategy, project-based learning, actively involves students in the resolution of complex, real-life situations (Hmelo-Silver, 2004). In contrast to traditional teaching methods that are subject-centred and focus on teacher-driven instruction, it entails the integration of multiple disciplines into one project where students work collaboratively on a task that demands high level thinking (Kokotsaki et al., 2016). Furthermore, digital technology plays a crucial role in enhancing critical thinking skills by offering vast information and advanced analytical tools. Open discussions, higher-order questions, and assignments that require deep analysis and reflection while encouraging class participation are some of the ways teachers can help students think critically.

Critical thinking skills, as conceptualised within the present research, align with Ennis (1989) definition: the capacity for rational and reflective thought intended to ascertain what to believe or how to act. This cognitive approach simultaneously cultivates intellectual curiosity and impels individuals to pursue further knowledge, consequently expanding their comprehension. Within this study, five indicators are employed to categorise students' critical thinking abilities: elementary clarification, basic support, inference, advanced clarification, as well as strategy and tactics.

Elementary clarification includes identifying and clarifying the problem or question being asked. Basic support involves evaluating information sources and supporting the arguments presented. Inference relates to the ability to make conclusions based on available evidence and predict the implications of those conclusions. Advanced clarification involves the analysis and interpretation of more complex information or arguments. Finally, strategy and tactics include the ability to develop strategies or plans to solve problems and evaluate the effectiveness of these solutions. These indicators allow a comprehensive assessment of students'

critical thinking abilities in various stages of project-based learning with a STEM approach (Ennis, 1989).

METHODOLOGY

Quasy-experimental approach implemented in this study, which used pretest-posttest control group design. This study only involves one class who has given treatment in the form of the STEM Integrated Project Based Learning Model. This study empirically and theoretically examines how STEM-PjBL empowers students' critical thinking skills in science. In this context, the STEM-PjBL learning model constitutes an independent variable, while critical thinking skills represent the dependent variable.

All fifth-grade students at SDI Surya Buana Malang serve as the population of this research. A total of 24 students from one class of fifth grade were randomly selected as the sample to ensure diverse representation. While this sample size is limited, it provides a foundation for exploring the effectiveness of STEM-PjBL. For the next studies, it's essential to secure a larger, more diverse sample across different schools to enhance generalisability.

The critical thinking test instrument consisted of five essay questions aligned with the indicators of critical thinking based on Ennis (1989). The test was validated through expert reviews involving two education specialists, ensuring content validity. Whereas Cronbach's alpha provided the basis for establishing reliability, yielded a score of 0.805, indicating high reliability. The instruments were pilot tested on a similar group of students to ensure clarity and functionality before the main study.

The research procedure begins with preparation, where the researcher prepares all research instruments, including the lesson plan and critical thinking test, and validates the test. Furthermore, the pretest gives students a critical thinking test to measure their initial abilities before being given treatment. Following this, students receive lessons utilising the STEM Integrated PjBL model, consistent with the prepared lesson plan. Post-treatment, students completed another critical thinking test (post-test) to measure changes in their skills after using the STEM Integrated PjBL model. The collected data were subsequently analysed using normality and Paired Sample T-Test techniques to determine the treatment's efficacy.

RESULTS

Description of STEM Integrated Project-Based Learning

The STEM-integrated Project Based Learning model, as delineated by Laboy-Rush (2011), encompasses five key components: reflection, research, discovery, application, and communication. The reflection stage is the earliest step in the STEM Integrated Project Based Learning Model. At this stage, students are expected to evaluate the knowledge that students have previously acquired. Students are invited to realise the concepts that have been understood before and identify concepts that require further development. At this reflection stage, the teacher also provides

a problem of context related to changes in the form of objects. Then students are asked to observe videos of changes in the form of objects and plan the steps of the project to be carried out. Thus, the reflection stage prepares students cognitively and emotionally to continue to the next stage and builds a strong foundation for deeper learning.

In the Research stage, students begin digging deeper into the topic or problem to be solved in the project. Students engage in various research activities starting to collect relevant information and build a deep understanding of changes in the form of objects. Students collect information from books, articles, or other online sources related to changes in the form of objects related to the context of the problem presented earlier. The teacher becomes a facilitator and directs students to determine which information can be used. Based on the information collected, students are invited to determine the steps of the investigation process that will be carried out. The results of the information that has been collected become the basis for continuing to the discovery stage.

In the discovery stage, students prepare the flow of experiments to be carried out based on the Learner Worksheet provided by the teacher. Students are encouraged to develop projects related to changes in the form of objects. Students learn to use relevant tools and technology to produce their projects at this stage. Students also attempt to fine-tune the design of a given project so that it can run as desired. They record the procedure for preparing the project design on the Learner Worksheet handed out prior to the class.

The last stage in the STEM-PJBL approach is the application stage where some of the ideas and solutions that the students have embraced in their earlier staged are used in solving real life problems. For instance, the students' work could be a model indicating how ice and water are related by transformation or the result of boiling water which transforms into steam. Students will implement the model in a live environment at this stage and check whether the results show the expected outcome. They might try to use ice and water in different conditions and analyse the difference in change of form themselves to be aware that their model does work in real life rather than in lab or at school.

The communication phase is the phase where students showcase their work in front of an audience, be it fellow students, teachers or even the parents. Within the context of changes in state, the students shall explain their discoveries and observations such as the case with ice melting at a given temperature or steam formation when water is heated. They will exhibit the models or experiments they've accomplished, describe how they solve a problem, and when encountering an issue, how they get around it. In this way, they show the students how to express their conceptions and outcomes and stabilise the material in their mind through discussions with other people. The example of the student work project shown in Figure 1.



Figure 1. Example of student work project
Source: Authors' own work

Description of Students' Critical Thinking Skills

Evaluation of critical thinking skills was conducted by pre-test and post-test scores. The pre-test yielded an average score of 62,917 (SD = 9,659), increasing to 75 (SD = 10,529) in the post-test. The observed range, spanning a minimum pre-test score of 40 to a maximum post-test score of 90, indicates a comprehensive enhancement in students' critical thinking capabilities following the STEM-PjBL treatment. This research provides additional corroboration of prior studies suggesting that combining STEM with project-based learning creates a relevant framework for students to engage in critical thinking in problem-solving contexts (Han et al., 2015; LaForce et al., 2017). The STEM-PjBL methodology notably fosters student engagement throughout all stages of critical thinking, including problem identification, data analysis, and the development of data-driven solutions. This aligns with the findings of Hanif et al. (2019), who reported that STEM-PjBL fosters enhanced critical thinking skills and improved collaborative problem-solving among students.

This research's innovative contribution is its demonstration that the STEM-integrated PjBL paradigm, characterised by reflection, inquiry, discovery, application, and communication, markedly improves students' critical thinking abilities (LaForce et al., 2017). The preliminary stage of this educational framework is reflection, during which students analyse their misconceptions and recognise apparent inadequacies in their understanding (Mulyani & Arif, 2021). The research phase encourages students to collect comprehensive information regarding the subject of study (Muzana et al., 2021). Furthermore, students develop and consolidate their initiatives throughout the discovery phase using suitable tools and technology (Pramasdyahsari et al., 2023). The application step involves employing concepts to address real-world issues, whereas the communication stage requires presenting project outcomes from multiple students to an audience (Laboy-Rush, 2011).

The Effect of STEM Integrated Project-Based Learning on Students' Critical Thinking Skills

This investigation empirically and theoretically seeks to determine if students' critical thinking skills are augmented subsequent to their exposure to the STEM Integrated Project Learning strategy. As a prerequisite for hypothesis testing, a normality assessment was executed utilising the Kolmogorov-Smirnov test with Lilliefors correction, facilitated by the SPSS 27.0 software. The derived significance value of 0.061 (> 0.05) affirmed the normal distribution of the critical thinking skills data, thereby validating the continuation with parametric statistical hypothesis testing.

The hypothesis of this study posited that students' critical thinking skills will enhance in both practical and theoretical contexts following the implementation of the STEM Integrated Project Learning technique. The SPSS program and a Paired Sample T-Test at a 5% threshold of significance were used to test this. The analysis yielded a t-coefficient of 6.201 and a significance value of 0.000 ($p < 0.05$). Consequently, statistical analysis resulted in the rejection of the null hypothesis in favor of the alternative hypothesis. This study validates that STEM-PjBL may effectively enhance students' critical thinking abilities. The models work well in practice, as shown by the fact that post-test scores (75) are much higher than pre-test levels (62.917). This finding highlights the significance of STEM-PjBL as a potentially effective pedagogical approach for equipping elementary children to face the problems of the 21st century.

In line with previous research (Han et al., 2015; Ismail et al., 2016; LaForce et al., 2017), our study confirms that STEM subjects have the ability to improve students' practical skills. Through the use of authentic, real-world problems, STEM-PjBL helps students develop their critical thinking skills. Motivates pupils to enhance their cognitive performance by demanding that they traverse complicated challenges with (Mulyani & Arif, 2021a; Pramasdyahsari et al., 2023; Wang et al., 2023). Ismail et al. (2016) and Prayogi (2023) found that students who used STEM-PjBL had better critical thinking skills.

The efficacy of STEM-PjBL in enhancing students' critical thinking skills has also been established in prior research, which attributes this improvement to the model's encouragement of applying STEM knowledge in real-world settings (Hanif et al., 2019; LaForce et al., 2017). Students must think analytically and creatively when developing projects, which hone their ability to evaluate and solve problems with innovative methods (Mulyani & Arif, 2021). In addition, STEM-PjBL facilitates collaboration that supports students' ability to question, criticise ideas, and solve problems together, which is also the core of critical thinking skills (Bulu & Tanggur, 2021).

Apart from promoting critical thinking among students, incorporating STEM into learning fosters students' learning

participation (Han et al., 2015). Capraro and Slough (2013) supported this study that STEM integration also increased the level of engagement and knowledge in PBL setting. On that note, one can realise that when students participate in STEM projects, they acquire academic content and operating technological knowledge as well as systematic understanding.

The following is the reason why STEM becomes integrated into learning, taken from Mulyani and Arif, (2021) states that the integration of STEM on project-based learning shows that the students' motivation can improve and there is an opportunity of the students to apply the knowledge in real life. The studies presented by them proved that students in STEM projects were found to have enhanced their analytical skills and problem-solving pits, thus supporting our study.

An analysis of the present study reveals that STEM-integrated PjBL enhances learners' critical thinking skills. It also incorporates project approach and some STEM components which helps the students to reason and conceptualise (Han et al., 2015; LaForce et al., 2017). The learners are presented with contextual problems related within the STEM integrated of an environment that they have to solve through an integrated approach (Pramasdyahsari et al., 2023). For instance, when students are assigned an environmental project where they are expected to come up with a solution, the use of science knowledge to understand the problem, technology knowledge as a means to look for a solution, engineering knowledge as means to designing a model of the solution, and mathematics as a tool of determining efficiency of the solution as postulated by Laboy-Rush (2011) and Lou et al. (2010). This involves memorisation of facts and ideas and also an ability to understand them, analyse, and apply such ideas or facts with reference to a real-life situation which is critical thinking (Capraro & Slough, 2013; Han et al., 2015).

Moreover, the critical thinking of students could be enhanced through collaboration and discussion as they solve such problems with others intensified (Bulu & Tanggur, 2021). While solving the problems in groups, students need to pose questions, evaluate other people's opinions, and come to a consensus on problem solving. Such activity basically forces a student to examine his or her own and other people's theories, analyse proofs, and make conclusions on the basis of thorough analysis (Han et al., 2015). For instance, every time the students come across different data or come up with experimental results that are different from the expected ones, they have to alter their strategies, find mistakes, and reconsider hypotheses that are all part of the critical thinking skills as concluded by Capraro and Slough (2013), and Han et al. (2015).

This research offers a new perspective in five learning stages identified by Laboy-Rush (2011), which help regarding the results of the learning process: knowledge evaluation and a presentation of a project (Lou et al., 2010). This approach enables

the students to develop their knowledge progressively and comprehensively, making it easier to learn since they guide the understanding of concepts step by step (LaForce et al., 2017).

Another strength of this study is the effort to highlight the communication stage of the intervention, which has been occasionally in other works (Bulu & Tanggur, 2021). For instance, Owens and Hite (2022) conducted a study focusing on the centrality of discussion and integration in PjBL. As for the study of Laboy-Rush (2011), it is rather evident that the model needed to become more specific in discussing the formal presentation stage. Therefore, there is a positive implication on this study as it emphasises on presentation and feedback from the audience meaning that, in the process of presenting concepts, the students are able to understand the same and even express their understanding to others while in the process of defending their work hence promoting the idea that understanding via communication also enhances knowledge retention (Muzana et al., 2021).

Therefore, the implications for educators and curriculum developers for discussion in this study are important. Besides, the incorporation of STEM in PBL enhances students' critical thinking skills and enables them to deal with challenges better as indicated by Han et al. (2015). This can be used across different content areas to enhance the students' perception of how information being taught in class relates to real life (Purwaningsih, 2020; Siew, 2018). Training also plays a crucial role in the teacher training process itself to enhance the implementation of this model, resulting in the improvement of flexibility and teaching efficiency (Pramasdyahsari et al., 2023).

DISCUSSION

This study proves that the use of Project Based Learning (PjBL) with an addition of STEM enhances the critical thinking abilities of the learners in elementary school. By the method that includes viewing process as a five-step journey- review, investigation, emergence, implementation, and reporting- a student not only enhances his/her comprehension of the received information but also develops skills in analysis and enumeration. Using the data derived from the statistical tests, it could be noted that the general performance of student in terms of critical thinking aptitude greatly improved in this lesson, as evidenced by the fact that the mean post-test score was higher than this pre-test mean score.

Integrating STEM into PjBL framework provides a transformative educational pathway that fosters critical thinking and 21st century skills such as creativity and collaboration. It also strengthens students' analytical faculties and readiness for real-world applications. By synthesising interdisciplinary STEM principles with active problem-solving, this model enhances both academic mastery and practical readiness. Consequently, this study positions STEM-PjBL as a versatile pedagogical model capable of bridging

the divide between classroom theory and professional practice.

The consequences of such findings are very crucial to education, particularly on the curriculum which is designed to meet the needs of the learners as they prepare for future endeavours. STEM integrated PjBL is used to implement an approach that results in students' mastery of both content knowledge and skills necessary to be effective in the twenty-first century, to include critical thinking abilities, collaboration, and problem solving.

LIMITATION AND RECOMMENDATION FOR FUTURE RESEARCH

It is vital to note the following limitations of this study even though the results demonstrate its effectiveness. First of all, the sampling of this study only involved a group of students from one primary school and therefore there is a possibility that the findings of this study may not be generalised to other large samples of different populations. Second, the study design deployed a limited timeframe to assess the effectiveness of STEM-integrated PjBL implementation on enhancing the students' critical thinking skills, and therefore, the findings may not reveal the longitudinal effects of this intervention decisively. The changes resulting from this approach in thinking patterns and habits, such as the transferability of the developed critical thinking skills or the process of their further development, have not been assessed in this study.

Besides, this research failed to investigate some of the difficulties faced by the students who require assistance when transitioning to the STEM-integrated PjBL learning model. Fluctuations in students' preparedness to embrace the technologies and their basic level of technological literacy were also not assessed as would have impacted students' performance. These limitations underline that more studies should be conducted to reveal the efficacy of STEM-integrated PjBL in various settings, for a longer period, and to discover how the aforementioned issues can be mitigated and potential solutions found.

Therefore, the following recommendations can be put forward for future research and practice grounded on the findings and limitations: Thus, more extensive studies should be carried out including higher number of participants from diverse schools and different socio-economic status of the families. This will assist in increasing external validity of the study thus to evaluate the potential scalability of the STEM-PjBL model across diverse educational settings. The STEM-integrated PjBL model can work in different contexts. Secondly, it is suggested that long term research should be conducted to assess the long-term effectiveness of this approach of enhancing students' critical thinking abilities and how these abilities have been used practically once learned. Further, it is crucial to design and analyse even more proficient support procedures concerning the students who fail to work productively in terms of STEM-integrated PjBL, such

as technology enhancement and the use of scaffolding to tackle the challenges that have been identified. At last, there is a necessity to design integrated assessment tools which will help the authors estimate not only final results, but all the aspects of students' complicated thinking activities in the context of the learning process in order to compare them with the results got through presented approach more successfully. These recommendations aim to refine the implementation of STEM-PjBL and contribute to the development of more robust instructional strategies.

CONCLUSION

This study set out to examine whether integrating STEM disciplines within a Project-Based Learning framework could strengthen elementary students' critical thinking skills within thematic science learning, an area in which empirical evidence at the elementary level had remained limited. The findings provide clear support for this proposition: students' critical thinking scores improved significantly following the STEM-PjBL intervention, with the paired sample t-test confirming that the increase from the pre-test ($M = 62.917$, $SD = 9.659$) to the post-test ($M = 75$, $SD = 10.529$) was statistically significant ($t = 6.201$, $p < .05$). These results substantiate the hypothesis that embedding STEM components into the five-stage PjBL cycle of reflection, research, discovery, application, and communication provides elementary students with a coherent and progressively scaffolded pathway for developing higher-order thinking, rather than leaving such development to incidental exposure within conventional, procedure-bound science instruction.

Theoretically, this study extends the STEM-PjBL literature by demonstrating that the model's benefits, previously documented mainly in secondary, vocational, and higher-education settings and within single-subject instruction, are also attainable within an integrated thematic curriculum at the elementary level. Practically, the findings offer elementary school teachers and curriculum developers a concrete instructional pathway for cultivating 21st century competencies without sacrificing the delivery of core scientific content, and they underscore the importance of structured teacher training and adequate resource support in sustaining the model's effective implementation.

Nonetheless, these findings should be interpreted in light of the single-school sample, the pre-experimental one-group design, and the relatively short intervention period outlined in the preceding section, which constrain the generalisability and longitudinal interpretation of the results. Future studies employing larger and more diverse samples, control-group designs, and extended observation periods are needed to corroborate and extend these findings. Taken together, however, the present study offers robust preliminary evidence that STEM-integrated Project-Based Learning constitutes a promising and transferable pedagogical approach for fostering critical thinking among elementary students within thematic science education.

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