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Research article

The RMS teaching model with brainstorming technique and student digital literacy as predictors of mathematical literacy

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ABSTRACT

In the field of educational sciences, combining various research studies is essential for the development of key competencies such as digital and mathematical literacy. However, there is a research gap in understanding the challenges of implementing the Reading, Mind Mapping, and Sharing (RMS) teaching model in Indonesian schools, which requires a model customised for the unique context of the Indonesian education system. The objective of this research is to assess the impact of the RMS teaching model on students' digital and mathematical literacy. The study employed a quasi-experimental design, consisting of two experimental classes and one control class. The first experimental class used the RMS teaching model with brainstorming techniques. The second experimental class used the RMS teaching model without brainstorming. The control class followed standard instruction based on the school curriculum. During the even semester, a total of 96 secondary school students from two different schools in Bandar Lampung, a province in Indonesia, participated in both the experimental and control groups. Data collection was carried out using a questionnaire and a test. To analyse the data, Winstep and SPSS applications were used. The study's findings supported for the effectiveness of the RMS teaching model combined with the brainstorming method in enhancing students' mathematical literacy and digital literacy. Students who were taught this approach demonstrated higher mathematical literacy skills compared to those who received instruction using the RMS teaching model and direct instruction methods. This model can act as a guide for teachers to modify their approaches creating a captivating learning atmosphere that matches the requirements of students.

1. Introduction

Mathematics is significant importance in both personal and academic contexts. It serves as a foundational skill required for problem-solving in various scenarios of work and daily life [1]. The concept of mathematical literacy emerges as a framework that encompasses the knowledge and abilities necessary to navigate the mathematical challenges encountered in everyday situations [2,3]. Mathematical literacy involves understanding and practical application of mathematical concepts in real-life or personal experiences [4,5]. Consequently, having mathematical knowledge becomes crucial, since people with these skills not only comprehend mathematics but also use it effectively to address complex situations [6].

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In the 2018 PISA survey, Indonesia's mathematical literacy was ranked 73rd out of 79 nations, scoring 379 [7]. It indicates that the mathematical literacy of Indonesia's is significantly lower compared to other countries. Similarly, in the 2015 PISA survey, Indonesia ranked 65th out of 72 nations, with a score of 386 [8]. Several previous studies have also highlighted the inadequate mathematical literacy skills of Indonesian students [9,10]. It is evidente that there is a pressing need to improve students' mathematical literacy through effective and efficient teaching and learning models [11].

The Reading, Mind Mapping, and Sharing (RMS) teaching model aligns with the principles of 21st-century learning proposed by UNESCO and the constructivist learning philosophy [12]. Rotated in the consturctivist concept, the RMS teaching model, learning is designed to be consistent with the constructivist concept, which emphasises that learning is not only the absorption of knowledge, ideas, and skills but also the actively constructing and developing of knowledge by the students themselves [13]. This approach fosters the cultivation of autonomous, creative, and responsible knowledge among students within an interactive learning environment facilitated by educators [13]. In this study, the authors aims to enhance the learning process by integrating the RMS teaching model with the brainstorming technique to maximise student participation and encourage critical thinking.

The brainstorming technique is a learning process that prioritises collecting ideas, information, and experiences from students to generate a diverse range of responses to a problem posed by an educator during the learning process [14]. Its goal is to encourage students to express their ideas extensively. Alex Osborn first introduced this brainstorming technique in the 1930s [15]. In his book, called "Applied Imagination," he outlined four fundamental guidelines for the brainstorming technique: (1) refrain form criticising ideas, (2) allow freedom to express opinions or ideas, (3) generate as many ideas as possible, and (4) integrate and refine ideas [16].

In Busnawir's research [17] it was found that digital literacy can signifanctlty influence mathematics literacy. Since the 1990s, digital literacy has become increasingly interwined with technologycal advancements [18]. Digital literacy encompasses the ability to effectively use information and communication technology for various tasks, including acquiring, comprehending, analysing, designing, and communicating digital information [19]. Integrating digital literacy into mathematics learning can broaden students' interaction opportunities, provide access to engaging Reading materials, offers diverse references sources, facilitate the use of information and communication technology, and simply problem-solving processes. Moreover, it helps studnets fostering a mathematically critical mindset, enabling students to discern and use good, relevant, and high-quality digital information effectively [20].

Despite the increasing interest in interactive and student-centred learning approaches, addopting of the RMS teaching model with the brainstorming technique is still limited in Indonesian classrooms. Traditional teaching methods, teacher-centred approaches, and content-driven curricula often dominate the educational landscape in Indonesia. Concequently, there is a significant research gap in understanding the feasibility and effectiveness of implementing the RMS teaching model within the Indonesian context.

Furthermore, there is a lack of empirical studies specifically examining the challenges and opportunities associated with the RMS teaching model in Indonesian schools. Factors such as limited resources, large class sizes, time constraints, and cultural dynamics can significantly impact the successful implementation of the RMS teaching model. Understanding these contextual factors is crucial to tailoring the model to meet the unique needs and challenges of the Indonesian education system.

By addressing this research gap, the study aims to enrich to the current literature on innovative teaching models in Indonesia. The findings will provide valuable insight on the feasibility, effectiveness, and potential benefits of integrating the RMS teaching model with the brainstorming technique to promote active learning, critical thinking, and collaboration among Indonesian students. Additionally, the research aims to pintpoint the specific challenges and barriers that must be addressed for successful implementation, thus guiding policymakers and to educators in creating supportive learning environments that encourage student engagement and creativity.

The goal of this study is to evaluate the effect of the RMS teaching model on students' mathematical and digital literacy skills. The following research questions are outlined.

(1) Does the instrument count as valid and reliable based on the Rasch measurement model?
(2) Is there a significant difference between mathematical literacy and digital literacy based on gender during the implementation of the RMS teaching model?
(3) Is there a significant relationship between mathematical literacy and digital literacy during the implementation of the RMS teaching model?

2. Literature review

2.1. RMS teaching model

In educational studies, the RMS teaching model, which stands for the "Reading, Mind Mapping, and Sharing", represent an instructional approach that integrates reading activities, mind-mapping techniques, and collaborative sharing among students [21, 22]. The Reading component involves students engaging with written texts, such as textbooks, articles, or other relevant materials, to acquire knowledge and understanding of a particular subject [23]. It emphasises the importance of reading comprehension and information gathering. The Mind Mapping component involves visual mapping techniques to organise and represent ideas, concepts, and relationships [24]. Students create diagrams or graphical representations connecting key points, enabling them to visualise and explore the connections between different ideas. The Sharing component focusses on collaborative learning and communication among students. Provides opportunities for students to share their thoughts, perspectives, and mind maps with their peers, either through small group discussions or whole-class interactions. This process of sharing encourages active participation, critical thinking, and the exchange of ideas [25]. In the context of the role of the teacher in sharing, instructors play a crucial role in facilitating and guiding these sharing activities [26]. They can create a conducive environment for open discussions, encourage students to express their ideas confidently [27], and provide insightful feedback that fosters deeper understanding and knowledge exchange [28]. The teacher acts as a moderator, ensuring that the sharing sessions contribute to a collaborative and enriching learning experience for all involved students [29].

The RMS teaching model aims to foster active learning, conceptual understanding [30], critical thinking [31], creative thinking [32], literacy, and meaningful collaboration among students [13]. It provides a structured framework that enhances students' comprehension, critical analysis, and communication skills. By integrating reading, mind mapping, and sharing, the RMS model supports students in constructing knowledge, making connections, and developing a deeper understanding of the subject matter [33]. Overall, the RMS teaching model is designed to promote student engagement, cultivate higher-order thinking skills, and facilitate a collaborative learning environment in educational settings.

The study by Muhlisin aimed to investigate the effectiveness of the RMS teaching model in improving metacognitive skills related to basic science concepts [13]. The results of the study indicated that the RMS teaching model significantly improved metacognitive skills among the participants, regardless of academic ability levels. Specificallly, the planning indicator and goals-setting, demonstrated the highest leve lof metacognitive skills with a value of 90 %. Moreover, the impact of the RMS teaching model on metacognitive skills was also reported to be 51.5 % higher compared to the teaching model commonly used by teachers, as described in the school curriculum. These findings underscore the positive influence of the RMS teaching model has a positive impact on the development of metacognitive skills in the context of science education. The study highlights the importance of incorporating innovative instructional approaches, such as the RMS teaching model, to enhance students' metacognitive abilities and deepen their understanding of science concepts.

Another study by Mutiara aimed to analyse the impact of the RMS teaching model supported by props, PowerPoint, and worksheets (PPW) on mathematical critical thinking skills [34]. This study contributes to the field of mathematics education by examining the effectiveness of a combined instructional approach (RMS teaching model assisted by PPW) on the development of mathematical critical thinking skills. By investigating the effectiveness of this instructional method, the study provides valuable insights into innovative approaches to promote critical thinking skills among mathematics students.

In conclusion, multiple studies have demonstrated that the RMS teaching model significantly improves students' learning outcomes accross a range of áreas, including reading comprehension, conceptual understanding, participation, problem-solving skills, creativity, and metacognitive abilities. The structured framework of the RMS teaching model promotes active learning, critical thinking, and collaborative practices, as evidanced by its multifaceted positive impact on student development. These findings underscore the effectiveness of the RMS teaching model in fostering holistic students growth.

2.2. Digital literacy

Digital literacy refers to the ability to engage effectively and critically engage with digital technologies, tools, and resources [35]. It entails acquiring skills, knowledge, and attitudes necessary to navigate, evaluate, create, and communicate using digital devices and platforms [36]. This broad skill set includes basic computer skills, information literacy, media literacy, communication skills, and responsible digital citizenship [37]. It is indispensable for full participation in the digital age, enabling individuals to access information, solve problems, make informed decisions, and participate in digital communication and collaboration. Moreover, digital literacy is an ongoing process as technology continues to evolve, requiring people to continuously develop and adapt their skills to the evolving landscape of digital technologies.

Digital literacy is a multifaceted concept that has been received considerable attention in the fields of education and technology. Previous research has delved into various dimensions and implications. For example, a study by McShane examined the role of public libraries in promoting digital literacy and fostering participatory culture [38]. The research explores how public libraries can serve as crucial community spaces to facilitate digital literacy practices and involve people in participatory activities within the digital realm. Findings from the study indicate that public libraries play a crucial role in promoting digital literacy and fostering participatory culture by providing access to technology, delivering educational programmes, and creating inclusive environments for community participation. This research emphasises the importance of public libraries as democratic institutions that support social inclusion and empower people to become active participants in the digital age.

Furthermore, in a study by Meyer's, the research is focussed on the increasing importance of digital literacy in the digital age and the need for individuals to navigate and interact effectively in online environments [39]. It specifically examines how students' levels of digital literacy relate to their ability to self-regulate their behaviours, emotions, and interactions when engaging in online activities. The findings reveal a positive and significant relationship between undergraduate students' digital literacy and their self-regulation in online interaction. Higher levels of digital literacy are associated with higher self-regulation skills [40], including the ability to manage online behaviours [41], control emotions [42], and maintain positive interactions in virtual settings.

In today's increasingly digital world, digital literacy has become a vital skill set for individuals of all ages and across various domains. It empowers individuals to access information, communicate, solve problems, and participate fully in digital societies. Digital literacy is important not only for personal use, but also for educational, professional, and civic engagement purposes. It is worth noting that digital literacy is an evolving concept as technology continues to advance and new digital tools and platforms emerge. Therefore, ongoing learning and adaptation are necessary to remain digitally literate in an ever-changing digital landscape.

2.3. Mathematical literacy

In the educational context, mathematical literacy refers to individuals capacity to understand, interpret, and critically evaluate mathematical concepts, information, and problem-solving strategies. It encompasses a range of skills and competencies that allow people to apply mathematical knowledge in real-world contexts, make well-founded decisions based on quantitative data, and effectively communicate mathematical ideas effectively [43].

Mathematical literacy goes beyond simply solving mathematical equations or performing calculations. It involves the ability to analyse and interpret numerical data, recognise patterns and relationships, reason quantitatively, and make sound judgments based on mathematical information [44]. It also includes the ability to effectively communicate mathematical ideas and arguments, when orally or in written form. In an educational setting, mathematical literacy is an essential goal of mathematics education. The purpose of this project is to equip students with the knowledge, skills, and dispositions necessary to navigate the mathematical aspects of daily life, work, and citizenship. It emphasises the practical application of mathematical concepts and techniques to solve real-world problems, make informed decisions, and participate meaningfully in society [45].

Mathematical literacy is closely related to other important skills, such as critical thinking, problem-solving, and data analysis. Encourage students to think flexibly, reason logically, and approach mathematical challenges from multiple perspectives. It also promotes an understanding of the role of mathematics in various fields of study and its relevance to everyday life [2] and fosters students' cognitive development [46]. In general, mathematical literacy in the educational context emphasises the development of mathematical knowledge, skills, and attitudes that enable people to engage with and critically evaluate mathematical information and ideas in a meaningfully and purposefully way.

The research study by Bolstad focusses on exploring how lower-secondary students engage with mathematical literacy in their learning experiences [47]. The study examines how students understand and apply mathematical knowledge in various contexts and situations. The findings of the study contribute to our understanding of how students engage in mathematical literacy and provide information on instructional practices that can support the development of mathematical literacy skills in lower-secondary education. Research highlights the importance of creating meaningful and authentic mathematical learning experiences that foster students' mathematical understanding and application beyond the classroom. Overall, these studies offer valuable information on the students'experiences in lower secondary school with mathematical literacy, providing a deeper understanding of how students navigate and make sense of mathematical concepts in their daily lives.

Another study by Yang, focusses on understanding the theoretical frameworks and instructional approaches used in science and maths literacy instruction, as well as the results and effectiveness of these approaches [48]. The authors examine a wide range of research studies published in academic journals and other reputable sources to gather relevant data. He also highlight the importance of linking theory and practice in literacy instruction, emphasising the need for evidence-based instructional strategies that align with theoretical frameworks. Additionally, he discusses different instructional approaches, including inquiry-based learning, project-based learning, and technology-enhanced instruction, and their impact on literacy outcomes in science and maths. The study highlights the importance of integrating literacy skills into science and maths education and offers implications for curriculum design and teacher professional development in this domain.

3. Methods

3.1. Participants

This study included 96 secondary school students from the Bandar Lampung region of Lampung province, Indonesia. The characteristics of the study participants varied by sex, student residence, and race. The demographics of the participants are followed in Table 1.

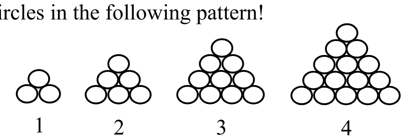
3.2. Instruments

There were two research instruments: a mathematical literacy test and a digital literacy questionnaire. The mathematical literacy test was developed using PISA 2018 indicators, which include seven competencies: (1) communication; (2) mathematisation; (3) representation; (4) reasoning and reasoning; (5) problem-solving strategies; (6) use of symbol language, formal language, technical language, and operations; and (7) use of mathematical tools [49]. The test contained six tasks. Fig. 1 shows the sample test. The grading is based on the students' ability to express their ideas, an indicator of mathematical literacy. This includes communication, mathematising, using symbolic, formal, and technical language and operation, and devising strategies for solving problems. The maximum score for each category is three points. Furthermore, Lukitasari et al. [36] added a digital literacy questionnaire totalling 18 questions

Table 1
The sample in this study.

Categories		*n*	Percentage (%)
Gender	Female	52	54.2
	Male	44	45.8
Living place	City	55	57.3
	District	41	42.7
Age	10 years old	18	18.8
	11 years old	69	71.9
	12 years old	9	9.4

Rania places a lot of circles in the following pattern!



How does Rania determine the number of circles in the 15th pattern if the circles are placed until the 15th?

Fig. 1. An example of a mathematical literacy test.

in Indonesian, with 3 factors: communicating digital contents (i.e., 4 items, "I write positive responses regarding assignments/discussions regarding information in online discussion forums"), exploring digital contents (i.e., 8 item, "I use presentation software (MS PowerPoint, storyline, video and the like) to do assignments and supporting lectures"), and creating and using digital contents (i.e., 6 items, "I use special software to support lectures (for example Mendeley, endnote, mindmaple lite, zoom, Mevideo"). The validity and reliability of the instruments were confirmed with χ^2 (318) = 101.835, $p = > 0.05$, RMSEA = 0.079, GFI = 0.900, AGFI = 0.825, TLI = 0.939, and CFI = 0.951. It means that the instrument is valid and reliable [50].

3.3. Design and data analysis

The research conducted in this study was granted ethical approval by the Institutional Review Board of the Universitas Islam Negeri Raden Fatah Palembang, with ethics approval reference B-029/UN·09/PP.January 06, 2023, in accordance with the institutional guidelines established by the institution. The study employed a quasi-experimental design using cluster random sampling to select participants from population of eighth-graders. This study covers three distinct groups: two experimental classes and one control class. The first experimental class, which involved 32 students, was instructed to use the RMS teaching model incorporating brainstorming techniques. This involved an introduction to the topic, followed by an open-ended question or problem to encourage students to freely share ideas and possible solutions. After brainstorming, students worked in groups to discuss and evaluate the proposed ideas, applying the RMS model to reflect on their learning processes. Meanwhile, the second experimental class, also consisting of 32 students, experienced the RMS teaching model without the initial brainstorming phase. These students received lessons centred around reading, mind mapping, and sharing, encouraging them to reflect on their learning strategies and approaches. Finally, the control class, which included 32 students, received conventional instruction aligned with the standard school curriculum, involving direct teaching methods such as lectures, demonstrations, and teacher-led examples. The treatment of this study was about eight meetings. This structured design allows for a comparative analysis of the effectiveness of different teaching approaches on student outcomes. The 2013 curriculum explicitly promoting mathematical literacy abilities and the material is incorporated into the learning process. On the other hand, the treatment duration consisted of eight meetings, allowing for a comparative analysis of the effectiveness of different teaching approaches on student outcomes.

Before learning was accomplished, participants of this study received a digital literacy questionnaire. Following the instructional period, they completed maths literacy test items. Data analysis was conducted using SPSS version 25 to examine statistical distribution, including percentage, mean, standard deviation, correlation, and Analysis of Variance (ANOVA) [51]. We compared means among three groups with the ANOVA. ANOVA helps determine whether there are any statistically significant differences between the group means by calculating the F-statistic, which compares the variance between group means to the variance within the groups [52]. If the F-statistic indicates a significant difference, it implies that at least one group mean is different from the others. Additionally, was employed to explore the relationships between variables using structural equation modeling (SEM) [53]. Finally, WINSTEPS version 5.2.3.0 was utilized for instrument data analysis, examining the fit model of questions based on Rasch measurement, including Infit and Outfit MNSQ, Wright map, and DIF [54].

4. Results

4.1. Does the instrument count as valid and reliable based on the rasch measurement model?

4.1.1. Mathematical literacy instrument

The instruments task consists of six item tasks focussing on number patterns. Data analysis was carried out with Winstep. The summary of the analysis is given in the table below.

Table 2 illustrates the result of the statistical analysis using Rasch measurement. It can be seen that the person's measure for mean

Table 2
Summary of the person and item measured.

Object Measured	Measure [Mean/(SD)]	Separation	Reliability	Cronbach Alpha
Person	−0.38/(0.81)	1.45	0.68	0.99
Item	0.00/(0.80)	7.58	0.98	

and standard deviation (SD) was −0.38 and 0.81, respectively. Likewise, the item was mean = 0.00 and SD = 0.80. Additionally, the reliability for item and person was higher, at about 0.98 and 0.68, respectively. Furthermore, the Cronbach Alpha was 0.99. Rasch's measurements justify Outfit MNSQ between 0.05 and 1.08 and Outfit SZTD between −0.05 and 1.10. Fig. 2 shows the distribution of the order of fit of the items.

The findings depicted in Fig. 2 highlight the assessment of mathematical literacy, categorising Question number 2 (denoted as LM2) as relatively easier, while Question number 6 (symbolized as LM6) falls into the more challenging category. In particular, the Rasch measure affirms the validity and reliability of the seven items. The characteristic curves for the difficult and easy questions are illustrated in Fig. 3, providing a visual representation. Furthermore, Fig. 4 shows the test information function, providing information on the distribution of students' responses.

The distribution of the students' responses followed a normal distribution pattern. In simpler terms, the raw variation explained by items accounted for approximately 43.4 %, as indicated by the eigenvalue. Meanwhile, the variance explained by the individuals was around 13.2 %. To ensure the validity and reliability of the items, Rasch's measurement was employed. Fig. 5 further illustrates the explanation of the fit of the item based on the Wright map.

A graphical representation known as the Wright map, illustrated in Fig. 5, was used to illustrate the connection between the elements and the ability of the student, both depicted on the same logit scale [55]. In this representation, items were placed on the right side, while student abilities were displayed on the left side. The construction of the Wright map was based on the student's achievements in a mathematical literacy test, as depicted in Fig. 1. A higher logit score on the map corresponds to a more challenging item and a higher level of ability in students [54]. The map reveals that item 6 (LM6) is the least difficult, while item 2 (LM2) poses the greatest challenge. Otherwise, there are no DIF items due to the gender of both boys and girls (see Fig. 6). It means that the item can contribute to assessing mathematical literacy for students.

4.1.2. Digital literacy instrument

4.1.2.1. Internal reliability and convergence validity. We comprehensively evaluated the instruments, including the reliability of indicators, internal reliability, convergence validity, and discriminant validity. The reliability of the indicator, evaluated using loading factors (refer to Table 3), showed values ranging from 0.54 to 0.83, meeting the criteria where a loading factor >0.70 is recommended and 0.40 is considered acceptable [56]. The loading factors for the items in this study met the criteria for the reliability of the indicator. Internal reliability, measured using Cronbach's alpha and composite reliability (CR), showed Cronbach's alpha values between 0.83 and 0.98. Following the recommendation by Hair et al. that a cut-off value > 0.70 for CR is advisable [57], all coefficient values of CR in our study, as presented in Table 3, were high and met the recommended guidelines. Convergent validity, assessed through extracted average variance (AVE) with a cutoff value of 0.5 or greater, indicated that the instruments in this study achieved satisfactory convergent validity.

4.1.2.2. Discriminant validity. Discriminant validity, as proposed by Fornel and Larcker, is established when the correlation between the constructs is less than the square root of the AVE [58]. Therefore, to assess the validity of the discriminant data, the correlations between the constructs were contrasted with the square root of the extracted average variance. As indicated in Table 4, the correlations among the factors were found to be lower than the square root of the AVE, indicating satisfactory discriminant validity in all constructs can be seen in Table 4.

Fig. 2. Bubble wrap for the fit of the item.

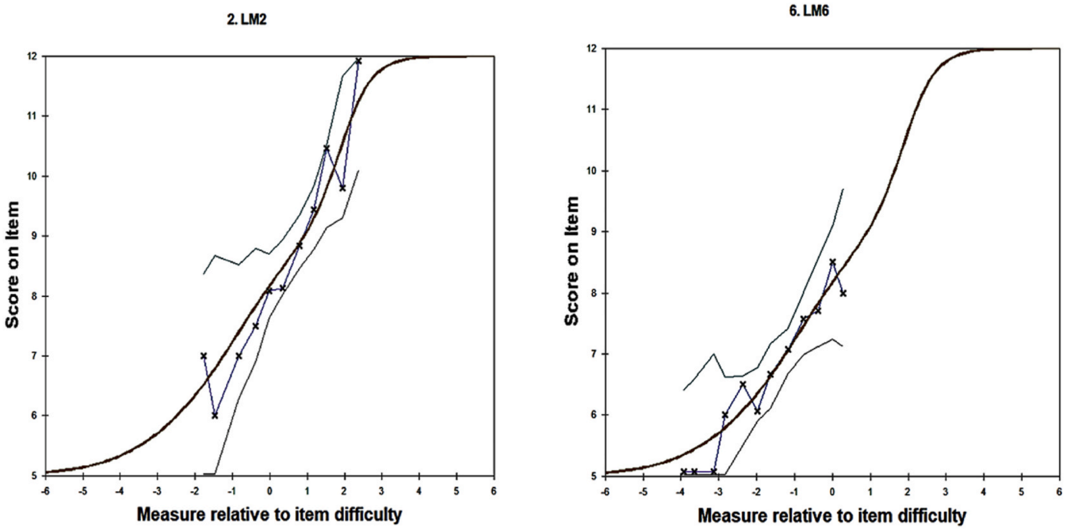


Fig. 3. Wrap map of easiest and hardest item questions.

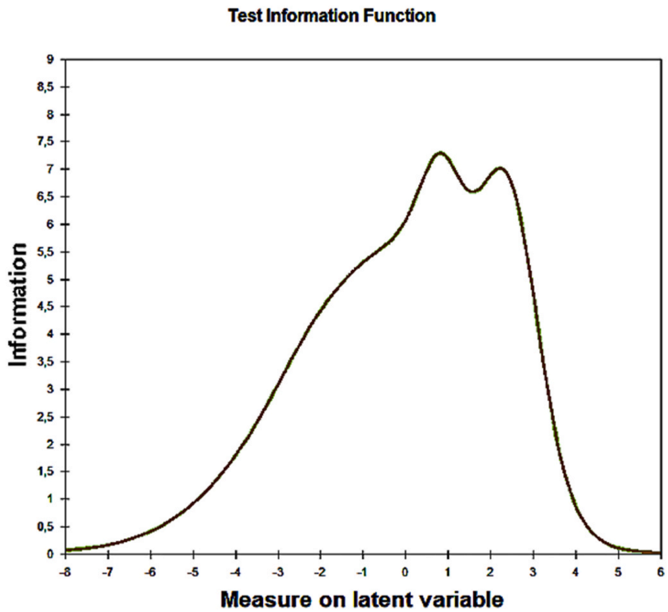


Fig. 4. Wrap map of the test information function.

4.2. Is there a significant difference between mathematical literacy and digital literacy based on gender during the implementation of the RMS teaching model?

The data analysis conducted using SPSS presented the critical remarks between mathematical literacy and digital literacy as shown in Table 5. Based on Table 5, there is a significant difference in students' mathematical and digital literacy across different classes. In Experiment 1, a notable difference was found between mathematical literacy (M = 8.43, SD = 0.65) and digital literacy (M = 3.60, SD = 0.47), as evidenced by t (31) = 30.86, $p < 0.001$, and a large effect size ($d = 0.88$). Similarly, in Experiment 2, a significant difference was observed between mathematical literacy (M = 7.84, SD = 0.64) and digital literacy (M = 3.42, SD = 0.57), with $t\,(31) = 31.02$, $p < 0.001$, and a considerable effect size ($d = 0.81$). Lastly, in the control class, there was also a significant difference between mathematical literacy (M = 7.29, SD = 0.61) and digital literacy (M = 3.32, SD = 0.54), with $t\,(31) = 31.02$, $p < 0.001$, and a medium effect size ($d = 0.73$).

Both Experiment 1 and Experiment 2 groups performed better in mathematical literacy and digital literacy compared to the Control group, as indicated by the higher means and $p < 0.001$) for all comparisons. The effect sizes (Cohen's d) for the differences in

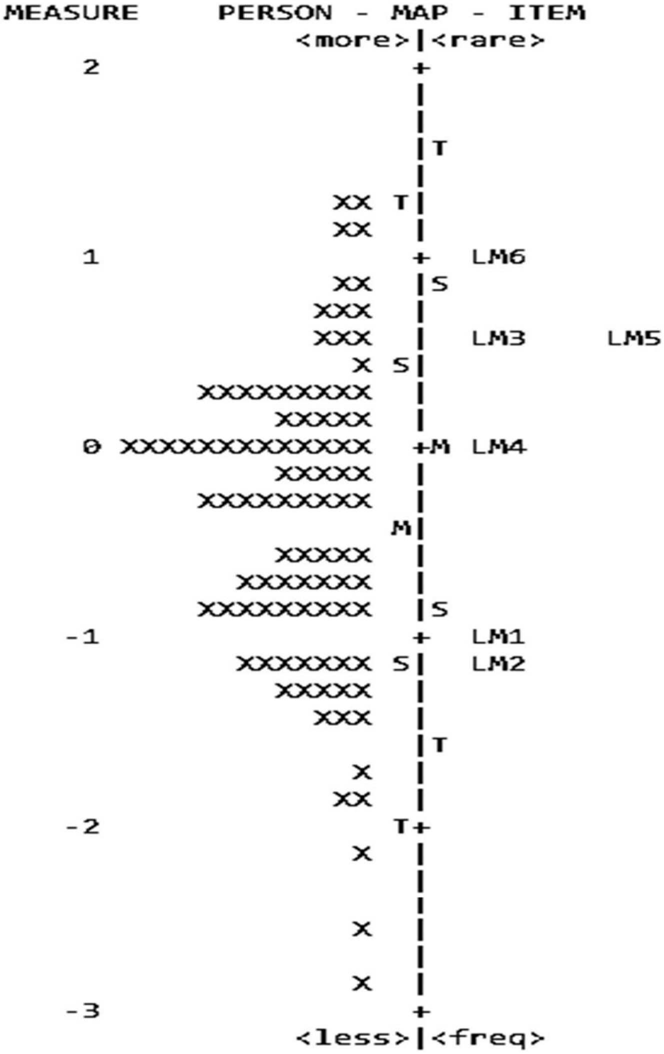


Fig. 5. Map of difficulty of the questions and student ability.

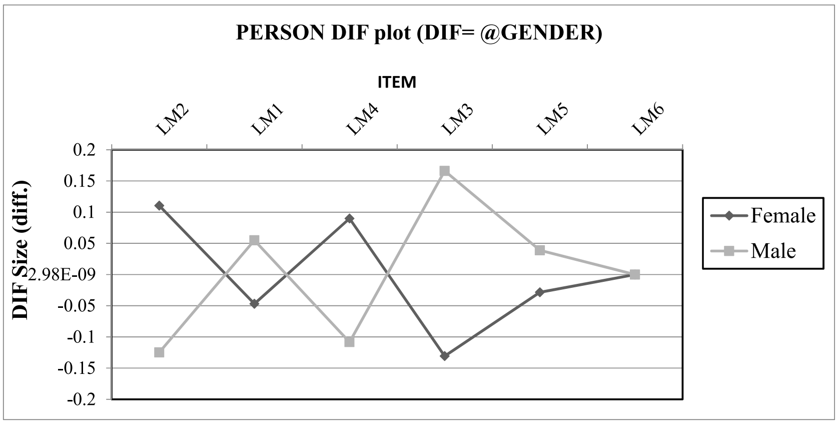


Fig. 6. The gender based on DIF items.

Table 3
Loading factor, reliability of the construct, and validity.

Latent variable of Digital Literacy	Loading factor	AVE	Composite Reliability	Cronbach's alpha
Communicating Digital Content		0.79	0.94	0.83
CDC1	0.56			
CDC2	0.83			
CDC3	0.62			
CDC4	0.56			
Creating and using digital content		0.79	0.96	0.98
CUD1	0.75			
CUD2	0.71			
CUD3	0.76			
CUD4	0.81			
CUD5	0.64			
CUD6	0.65			
Exploring Digital Content		0.67	0.94	0.93
EDC1	0.64			
EDC2	0.54			
EDC3	0.65			
EDC4	0.70			
EDC5	0.77			
EDC6	0.63			
EDC7	0.64			
EDC8	0.63			

Note: CDC = communication of digital content; CUD = creation and use of digital content; EDC = exploration of digital content.

Table 4
Discriminant validity HTMT.

	CDC	CUD	EDC
1. Communicating Digital Content (CDC)	–		
2. Creating and using digital content (CUD)	0.69	–	
3. Exploring Digital Content (EDC)	0.78	0.94	–

Table 5
Differences in students' mathematics and digital literacy.

Class	Variables	M	SD	*t*	*p*	Cohend's d
Experiment 1	Mathematical Literacy	8.43	0.65	30.86	<0.001	0.88
	Digital literacy	3.60	0.47			
Experiment 2	Mathematical Literacy	7.84	0.64	31.02	<0.001	0.81
	Digital literacy	3.42	0.57			
Control	Mathematical Literacy	7.29	0.61	31.02	<0.001	0.73
	Digital literacy	3.32	0.54			

Table 6
Gender differences among variables.

Class	Gender	Variables	M	N	SD	*t*	*df*	*t*	Cohen's d
Control	Female	LM	7.32	17	0.57	24.88	16	<0.001	0.67
		DL	3.26	17	0.50				
	Male	LM	7.27	15	0.68	18.96	14	<0.001	0.79
		DL	3.38	15	0.59				
Exp1	Female	LM	8.55	16	0.77	20.35	15	<0.001	0.97
		DL	3.59	16	0.45				
	Male	LM	8.30	16	0.49	23.75	15	<0.001	0.79
		DL	3.62	16	0.50				
Exp 2	Female	LM	7.97	19	0.54	27.72	18	<0.001	0.72
		DL	3.41	19	0.60				
	Male	LM	7.64	13	0.74	16.68	12	<0.001	0.91
		DL	3.43	13	0.53				

Note: $N = 96$; Exp1 = Experiment 1; Exp 2 = Experiment 2; LM = mathematical literacy; DL = digital literacy.

mathematical literacy and digital literacy are notable in all comparisons, ranging from 0.73 to 0.88, indicating a medium to large effect size [59].

Table 6 provides a comparison between male and female students in each class regarding their mathematical and digital literacy scores and also indicates whether the differences are statistically significant.

In the control class, there is a slight difference in mathematical literacy between female (M = 7.32, SD = 0.57) and male students (M = 7.27, SD = 0.68), with a small effect size (Cohen's d = 0.67). Although the mean scores are similar, the difference is statistically significant (t (16) = 24.88, $p < 0.001$). In digital literacy, male students had a slightly higher mean score (M = 3.38, SD = 0.59) than female students (M = 3.26, SD = 0.50), with a moderate effect size (Cohen's d = 0.79) and a significant difference (t (14) = 18.96, $p < 0.001$).

In Experiment 1, female students outperformed male students in mathematical literacy, with a mean score of 8.55 (SD = 0.77) compared to 8.30 (SD = 0.49) for males, resulting in a large effect size (Cohen's d = 0.97) and a significant difference (t (15) = 20.35, $p < 0.001$). For digital literacy, males scored slightly higher (M = 3.62, SD = 0.50) than females (M = 3.59, SD = 0.45), but the difference was not significant (t (15) = 23.75, $p < 0.001$) with the same effect size (Cohen's d = 0.79) for both genders.

In Experiment 2, the trend continued, with female students achieving a mean score of 7.97 (SD = 0.54) in mathematical literacy compared to male students' 7.64 (SD = 0.74), and a medium effect size (Cohen's d = 0.72). The difference was statistically significant (t (18) = 27.72, $p < 0.001$). In digital literacy, males slightly outperformed females, with a mean score of 3.43 (SD = 0.53) compared to 3.41 (SD = 0.60) for females, and a large effect size (Cohen's d = 0.91). The difference in digital literacy was significant as well (t (12) = 16.68, $p < 0.001$).

In summary, female students tended to perform better in mathematical literacy, particularly in Experiment 1. In digital literacy, male students had a slight edge, with notable effect sizes in the control class and Experiment 2.

Participants in the experimental classes demonstrated a greater improvement in mathematical literacy and digital literacy compared to those in the control class. These mean that mathematical literacy has had a positive effect on mathematical literacy. The results are visually depicted in Fig. 7.

4.3. Is there a significant relationship between mathematical literacy and digital literacy during the implementation of the RMS teaching model?

ANOVA was used to adjust the value of the dependent variable by mitigating the influence of the treatment effects. This process aims to reduce error variance by accounting for the hypothesised effects of covariate variables on analytical outcomes. Statistical covariance analysis can be used to protect groups from the impact of variables other than treatment variables [60]. The results of the one-way ANOVA test are provided below.

Table 7 illustrates the ANOVA results. The statistical analysis for the teaching method indicate that F (2, 95) = 32.597, $p < 0.001$, indicating that the teaching method (i.e., RMS teaching model that incorporates brainstorming techniques, the RMS teaching model and teacher instruction aligned with the standard school curriculum) influences the mathematical literacy of students. Additionally, the análisis reveals significant effects of the three different teaching models that have an effect on digital literacy, F (2, 95) = 71.361, $p < 0.001$. However, there is no significant effect on three different teaching models in relation to mathematical literacy and digital literacy, as indicated by F (4, 95) = 1.020, $p > 0.05$.

5. Discussion

Reading, mind mapping, and sharing are the three main steps of the RMS teaching model learning process [61]. At the reading stage, students participate in reading activities to enhance their critical thinking skills. Subsequently, at the mind mapping stage, they create mind mas to foster analytic thinking [62], aiding in information management and concept connection [63,64]. Unlike the brainstorming approach, which involves five phases in the learning process, namely providing information, identifying, classifying, verifying, and drawing a conclusion, the logical fallacy method has only two [65]. In this study, the RMS teaching model and the brainstorming technique were integrated to optimise the learning process. The combined approach begins with the instructor providing information about the subject to be discussed and its context (providing information). Only then does it enter the Reading stage, where educators guide students in critically reading specific topics or materials.

The mind mapping stages involves instructors assigning students to create personalised mind maps based on the outcomes of the knowledge they have acquired. Students are encouraged to express their thoughts and opinions [12]. To foster innovation and creativity, all ideas are welcome without criticism. Students may ask questions if they need clarification on the material (identification). After completion, the teacher places the students into heterogeneous groups and categorises their ideas according to the agreed upon criteria. Subsequently, students collaborate to create new mind map based on their critical reading, concept classification, and individual mind mapping results.

The sharing stages involves students presenting to collaborative group mind mapps to the class, facilitating discussions and questions. Educators provide feedback, reinforcement, and confirmation of material or subjects covered using various learning materials. Then, students are invited to study a collection of ideas (verification), and the educator directs them to draw different conclusions in solving the agreed-upon problem (conclusion).

Based on the results of the two-way analysis of variance, the second and three hypotheses are supported: the learning model influences the mathematical literacy skills of the students. Additionally, a follow-up test is required using the Scheffe test after a two-way ANOVA to see whether the average learning model for each sample class differs significantly. Based on the results of the Scheffe test

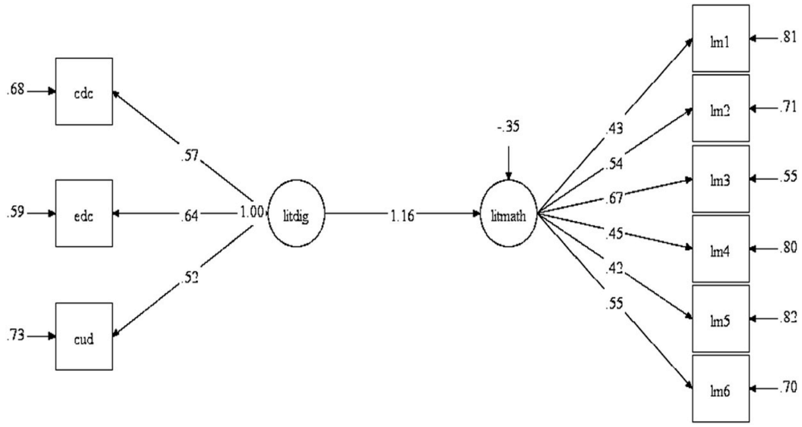


Fig. 7. The diagram of digital literacy has a potential effect on mathematical literacy.

Table 7
The results of a one-way ANOVA.

Source	Type III sum of squares	df	Mean Square	F	Sig.
Correction Method	4497.567[a]	8	562.196	34.584	<0.001
Intercept	396700.229	1	396700.229	24403.415	<0.001
Teaching_Method	1059.802	2	529.901	32.597	<0.001
Digital_Literacy	2320.065	2	1160.033	71.361	<0.001
Teaching_Method* Literacy_Digital	66.339	4	16.585	1.020	0.401
Error	1414.266	87	16.256		
Total	596860.000	96			
Corrected Total	5911.833	95			

Note: a. R Squared = 0.761 (Adjusted R Squared = 0.739).

calculations, it was determined that students treated with the RMS teaching model and brainstorming improved their mathematical literacy skills more than students treated with the RMS teaching model and direct teaching.

Based on the information provided above, the results obtained are consistent with previous research and studies demonstrating that the implementation of the RMS teaching model can improve the conceptual knowledge of students [66]. Further research indicates that the treatment of the RMS teaching paradigm (demonstration tools, power points, student worksheets) can enhance students' critical thinking skills [34]. In addition to previous research [67], the results of this study indicate that the stimulating high-order thinking skills model combined with the brainstorming technique can improve critical thinking skills and student motivation. Therefore, it can be inferred that teaching mathematical literacy abilities using the RMS teaching model and the brainstorming approach yields better outcomes than using the RMS teaching model and the direct instruction learning model. According to Wu and Cheng's research, classical classes (using e-books) significantly affect reading, reciprocal teaching, and mind mapping [68].

Digital literacy has an effect on the mathematical literacy of students. The hypothesis indicated that the digital literacy category has a substantial effect on the mathematical literacy skills of students. Mathematical literacy and digital literacy are two distinct yet interrelated competencies that are essential in the modern educational curriculum. Both skills are fundamental for students to thrive in the 21st century, where technology and mathematics intersect in numerous fields, including science, engineering, economics, and everyday life. Previous studies have shown that integrating digital tools in teaching mathematics enhances students' understanding and engagement. For example, Marcos found that the use of ICT in mathematics education can lead to improved student performance and motivation [69].

Modern educational standards emphasize the importance of both mathematical and digital literacy. The integration of technology in teaching mathematics to develop critical thinking and problem-solving skills [70]. Additionally, mathematical literacy can be enhanced through digital literacy by using digital tools for simulations, visualizations, and interactive problem-solving [71]. Conversely, understanding mathematical principles can help students better appreciate and utilize digital technologies effectively.

Both literacies support diverse learning styles and can cater to students with different strengths. For instance, students who struggle with traditional mathematical instruction may find digital tools helpful for visualizing and interacting with mathematical concepts [72]. Research by Niemi highlights that digital literacy is crucial for effectively engaging with mathematical content in digital formats, showing that students proficient in digital tools could better understand and manipulate mathematical information [73].

Comparing mathematical literacy and digital literacy within experimental and control groups is essential to understand the impact of innovative teaching methods versus traditional approaches. These variables are critical for preparing students to navigate an increasingly complex and technologically driven world. By analyzing how different instructional strategies influence these literacies, educators can develop more effective teaching practices that enhance student learning outcomes and better equip students for future challenges.

Based on the aforementioned facts, the results are consistent with previous research and demonstrate that digital literacy has a considerably favourable effect on students' critical thinking skills [74,75]. In addition, the another study suggests that digital literacy has a significant impact on learning outcomes [76–78]. Hence, studnets with high digital literacy levels tend to achieve better results in mathematical literacy compared to those with medium or low digital literacy. This is because students with a high level of digital literacy can use their skills to use digital technology to contribute to the widest possible range of reading materials with greater ease [79]. In other words, this is related to the findings of previous research, which indicates that students with high digital literacy categories can improve learning outcomes more effectively than students with low digital literacy categories [42,80].

6. Limitations and future research

Although this study provides valuable information on the relationship between digital literacy and mathematical literacy, it is important to recognise its limitations. First, the study was conducted with a relatively small sample size of 90 secondary school students from a specific region in Indonesia. Therefore, caution should be exercised when generalising the findings to other populations or settings. Future research should aim to replicate the study with larger and more diverse samples to enhance the generalisability of the results.

Second, the study relied on paper-pencil measures of digital literacy and mathematical literacy, which can be subject to response bias. Future research could incorporate objective measures or performance-based assessments to obtain a more accurate assessment of student literacy skills.

Additionally, the study solely examined the relationship between mathematical literacy and digital literacy, neglecting other potential factors that may effect students skills. Future research should explore the interaction between digital literacy and other variables, such as socioeconomic status, educational background, or teaching methods, to provide a more comprehensive understanding of the factors that contribute to the development of student literacy.

Furthermore, the study employed a quasi-experimental design with different treatment groups. Although this design allowed for comparisons between groups, it may not establish causal relationships definitively. Future research could employ randomised controlled trials or longitudinal designs to better examine the causal effects of digital literacy on mathematical literacy.

Finally, the study primaily focus on quantitatively analysing the data using statistical methods. Future research could incorporate qualitative approaches, such as interviews or observations, to gain deeper insights into students' perceptions, experiences, and strategies related to digital and mathematical literacy.

In conclusion, this study has shed light on the relationship between mathematical literacy and digital literacy among secondary school students. However, several limitations need to be addressed in future research to advance further our understanding of this topic and its implications for educational practice.

7. Conclusions

The study results demonstrated that both the mathematical literacy test and the digital literacy questionnaire were valid and reliable based on the Rasch measurement model. The analysis showed that the items and persons measures had high reliability, indicating that the instruments accurately assessed the students' abilities. Furthermore, there was a significant difference in the performance of males and females in both mathematical literacy and digital literacy.

The study also found a significant difference between the mean scores of the student's mathematical and digital literacy. Students demonstrated better performance in digital literacy compared to mathematical literacy. Additionally, there was a significant positive relationship between digital literacy and mathematical literacy.

The findings of the study supported the effectiveness of the RMS teaching model combined with the brainstorming approach in improving students' mathematical literacy. Students who were taught this approach showed higher mathematical literacy skills compared to those taught using the RMS teaching model and direct instruction. The results were consistent with previous research that highlighted the benefits of the RMS teaching model in enhancing conceptual knowledge and critical thinking skills.

Furthermore, the study emphasised the importance of digital literacy in enhancing students' mathematical literacy. Students with higher digital literacy skills demonstrated better mathematical literacy. These results underscores the important of integrating digital literacy into mathematics education to enhance overall proficiency.

In conclusion, the study provides evidence of the effectiveness of the RMS teaching model combined with the brainstorming approach in improving students' mathematical literacy. Additionally, it highlights the importance of digital literacy in improving mathematical literacy. These findings have implications for educators and policymakers in designing effective teaching strategies and incorporating digital literacy into mathematics curricula to foster students' overall literacy skills. Further research is recommended to explore additional factors that may influencing students' mathematical literacy and to investigate the long-term impact of digital literacy on students' academic achievement.

Data availability statement

Data will be available upon request.

CRediT authorship contribution statement

Komarudin Komarudin: Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization. **Suherman Suherman:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Formal analysis. **Tibor Vidákovich:** Resources, Investigation, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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