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RME-based Interactive Multimedia Activities to Improve Grade 8 Students' Performance in Mathematics

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Abstract

Despite ongoing reforms in instruction, many students struggle with abstract mathematical concepts. Hence, this study developed Realistic Mathematics Education (RME)-based interactive multimedia activities and examined their effects on students' mathematics performance. Following the Research and Development method, the interactive multimedia activities aligned with Realistic Mathematics Education principles were developed using PowerPoint with Visual Basic for Applications integration. An achievement test was used to ascertain the mathematics performance of forty-one Grade 8 students. Focus group discussions and journal entries were analyzed using thematic analysis to determine students' perceptions of the activities. Descriptive analysis revealed that students with "outstanding" proficiency levels increased by 29%, and those with "did not meet expectations" decreased by 41% after the implementation. The t-test result showed that students' achievement test scores increased ($t = 6.42$; $p < .001$), with a large effect size ($d = 1.002$). Additionally, five subthemes related to students' positive perceptions of the developed activities were identified: (1) personal beliefs, (2) positive mindset, (3) inquiry learning, (4) authentic learning, and (5) mathematical understanding. This study demonstrates an accessible and practical approach for creating interactive multimedia activities to advance pedagogical applications of the RME framework.

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Interactive Multimedia; Mathematics Performance; Realistic Mathematics Education; Research and Development; Visual Basic for Applications

INTRODUCTION

Mathematics education faces challenges in achieving meaningful learning among students, particularly at the high school level. Studies reveal that among the factors affecting students' learning, their inability to connect mathematical concepts to real-life situations remains a significant concern (Bacong et al., 2023; Kaya & Keşan, 2023). For this reason, students often perceive mathematics as abstract and irrelevant to their everyday experiences (Ahmad et al., 2024). This phenomenon hinders the effective internalization of knowledge, the enhancement of critical thinking, and the development of problem-solving skills (Deniz & Uygur-Kabael, 2016).

The nature of instructional materials contributes to the disconnect between reality and mathematical concepts, which in turn impacts students' learning (Chand et al., 2021; Waswa

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& Al-kassab, 2023). To address this issue, Yilmaz (2019) argued that the design of mathematics instruction must cater to students' individual learning experiences. As a result, Realistic Mathematics Education (RME) has emerged as a promising pedagogical framework that anchors mathematical learning in meaningful and real-world contexts. Grounded in the principle that mathematics should be experienced as a human activity, RME places learners' reality and authentic experiences in everyday life as the starting point of learning (Laurens et al., 2017). RME primarily aims to increase the relevance of mathematics in students' individual experiences by interacting with real-world problems and reconstructing mathematical knowledge (Palinussa et al., 2021; Sutarni et al., 2024).

In the case of the Philippines, the country has a longstanding problem of poor performance in mathematics. This problem is evident in the results of the recent Program for International Student Assessment (PISA) 2022, where the Philippines scored only 355 points compared to an average of 472 points among participating countries (OECD, 2023). Caraan et al. (2022) emphasized that the traditional instructional approach dominating the country's mathematics education system heavily affected its low performance in the international assessments. This situation limits students' appreciation of the subject, thereby reducing their interest and performance. Hence, local studies have advocated for the implementation of RME in the country's curriculum to improve mathematical learning outcomes (Dinglasan et al., 2023; Enriquez et al., 2024).

c on the design and delivery of appropriate instructional materials. Zubainor et al. (2020) highlighted five essential characteristics of RME-based lessons: (i) using real-life problems to start a lesson, (ii) using models or symbols to bridge learning from concrete to formal level, (iii) providing students with the opportunity to solve problems by themselves, (iv) facilitating students to interact, share, and construct solutions; and (iv) emphasizing the interrelationship of subject matters. With the widespread presence of technology, educators nowadays have multiple options to cater to these characteristics in the classroom. As such, this study hypothesized that interactive multimedia (IM) can effectively serve high school students with this range of RME characteristics (Lazarinis et al., 2022).

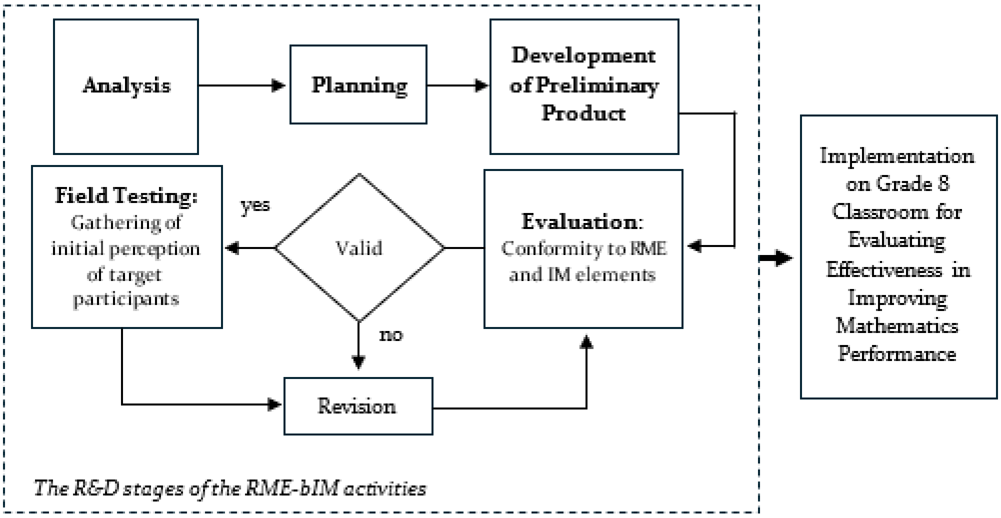
The development of IM for mathematics lessons leverages technology to enhance student engagement and understanding (Tsoukala, 2021). IM instructional activities integrate multiple forms of media, such as text, images, videos, animations, and simulations, allowing learners control over their use (Djamas et al., 2018). These instructional activities are valuable as they support guided knowledge construction through visualization, interaction, and feedback, which are also key characteristics of RME (Papadakis, 2020; Wijaya et al., 2020). Moreover, IM is flexible enough to accommodate independent, real-life problem-solving activities in the classroom (Beswick et al., 2023; Fredy et al., 2020). Hence, this study argues that computer-based IM activity is a potential fit for RME.

Despite the increasing availability of digital tools, research on integrating IM within the RME framework remains limited. More so in the Philippine mathematics education curriculum. This study addresses the gap by developing valid Realistic Mathematics Education (RME)-based interactive multimedia (bIM) activities. In particular, this study sought answers to the following objectives: (a) develop RME-bIM activities in mathematics; (b) investigate the improvement of students' performance after implementing the RME-bIM activities; and (c) examine students' perception of the implementation of RME-bIM activities.

METHOD

To develop the RME-bIM activities, this study employed the Research and Development (R&D) methodology (Borg & Gall, 1983) with modifications based on the stages utilized by Balacuit et al. (2024). Since this study aimed to improve learning outcomes, the R&D approach was appropriate for its structured, iterative process, which supports the systematic analysis, design, development, testing, and refinement of educational products. This method ensured that the developed activities were both pedagogically and technologically effective. It further ensured alignment with RME principles while exhibiting IM components. Figure 1 illustrates how the R&D process was embedded in the flow of this study.

Figure 1. Diagram of the flow of the study



A. Research Instrument

1. RME-bIM Activity Evaluation Tool (RAET)

The primary instrument used to evaluate the developed activities was the RAET. The instrument consisted of two main parts. The first part consists of IM indicators adopted from Septiani et al. (2020), which evaluate the media elements, instructional materials, and usability of the activities. These indicators assess visual clarity, content accuracy, navigational structure, and user control over the activities. The second part consists of RME indicators derived from Wahyudi et al. (2017) and Hikayat et al. (2020), including the use of contextual problems, learning progression, real-life problem solving, student interaction, and the interrelation of mathematical ideas. All indicators were rated on a four-level scale: 1 - "very low", 2 - "low", 3 - "moderate", and 4 - "strong" agreement with the criteria. This structure ensured that the RAET captured both the technological and pedagogical dimensions essential to evaluating RME-based IM activities.

This study used Fleiss' kappa (k) to measure the inter-rater reliability of the RAET. Fleiss' k was suitable because it accounts for agreement among more than two raters (Fleiss, 1971; Zapf et al., 2016). Five secondary mathematics teachers with master's degrees were asked to rate two IM activities using the RAET: one designed to intentionally incorporate RME principles and another that did not necessarily integrate RME characteristics. The results yielded $k = .61$ ($p < .001$) for the first activity and $k = .64$ ($p < .001$) for the second activity. These values indicate substantial and statistically significant inter-rater reliability of the RAET (Dumas et al., 2022; Landis & Koch, 1977). The result confirmed the RAET's reliability in evaluating RME-bIM activities.

2. Field Testing Perception Questionnaire (FTPQ)

To gather the initial perceptions of target students during the field-testing phase, the study employed a perception questionnaire adapted from Olipas (2023). The FTPQ was used to determine the appropriateness of the RME-bIM activities for the target learners prior to implementation. It assessed five dimensions of students' experience, including content quality, teaching and learning capacity, support capacity, assessment and feedback, and overall satisfaction. Each item was rated on a four-point Likert scale ranging from 1 - "disagree" to 4 - "strongly agree." The reliability evidence provided in the original study reported high internal consistency for all dimensions: content (α = .83), teaching and learning (α = .85), support (α = .87), assessment and feedback (α = .82), and overall satisfaction (α = .92). Cronbach's alpha values above .70 indicate an acceptable internal consistency (Brace et al., 2016; Plummer & Ozcelik, 2015).

3. Achievement Test

The Achievement Test was used to determine the students' performance in mathematics. In this study, this test was a 25-item multiple-choice summative test prescribed in the Philippine Department of Education (DepEd) Grade 8 curriculum materials. The test covers competencies such as basic concepts of probability, counting methods, and the probability of simple events. The researchers established the instrument's reliability prior to implementation. It was administered to 113 Grade 8 students. Reliability coefficients were computed using the Kuder-Richardson formulas KR-20 and KR-21. KR is a robust measure of internal consistency for dichotomously scored tests (Foster, 2021). The results yielded coefficients of .73 and .71 for KR-20 and KR-21, respectively. Both coefficients exceeded .70, which is the commonly accepted threshold for internal consistency reliability of tests (Setyaedhi, 2024).

B. Research Participants

This study implemented the developed RME-bIM activities with 41 Grade 8 students at a public secondary school in Dumingag, Zamboanga del Sur, Philippines. The participants were purposively selected based on two main criteria: their current enrollment in the grade level targeted by the developed activities and their voluntary willingness to participate in the study. This study deemed purposive sampling appropriate, allowing the researchers to intentionally select students required to learn the key mathematics concepts addressed in the RME-bIM activities.

C. Implementation Procedure

After the RME-bIM activities were deemed valid and acceptable for Grade 8 students, the third author implemented them. Before the implementation proper began, the Achievement Test was administered as a pretest. This phase established a baseline for evaluating improvement in mathematical performance. Over two weeks, the developed RME-bIM materials were used in regular mathematics instruction. At the end of each lesson, a focus group discussion (FGD) was conducted with a subset of participants to obtain immediate qualitative feedback on their experiences with the activities. Throughout the implementation, the researcher-implementer also noted observations, including patterns of student communication and interaction. Additionally, participants were asked to write brief journal entries after each lesson, reflecting on their understanding, challenges, and appreciation of the RME-bIM activities. After the two weeks, the same Achievement Test was administered as a posttest.

Meanwhile, this study adhered to established ethical guidelines for educational research. Prior to implementation, a letter of approval was obtained from the school principal, authorizing the third researcher to conduct the study. A written communication describing the purpose, procedures, and scope of the study was communicated to the participants and their parents or guardians. The communication indicated that participation is voluntary and that the participants may withdraw from the study at any time without consequence. Subsequently, signed parental consent was secured from each participant.

Confidentiality and anonymity were strictly maintained throughout the research process. Participants' names were coded during data entry. Only the researchers had access to the raw data. They were stored in a password-protected folder to prevent unauthorized access. Furthermore, in reporting the findings, all results were aggregated to ensure that no individual could be identified.

D. Data Analysis

Data analysis consisted of three major components. First, during the development phase, the ratings provided by the panel of evaluators using the RAET were analyzed to obtain arithmetic mean scores. Additionally, quantitative responses from the FTPQ were analyzed using the weighted arithmetic mean.

Second, the students' mathematics performance was examined using their scores on the Achievement Test. Their scores were summarized as percentage distributions and categorized according to the proficiency levels indicated in DepEd Order No. 8, s. 2015 (DepEd, 2015). These proficiency levels were "Did Not Meet Expectations", "Fairly Satisfactory", "Satisfactory", "Very Satisfactory", and "Outstanding". To determine the significance of the improvement of students' Achievement Test scores after the implementation of RME-bIM activities, a one-tailed paired-sample t-test was conducted. Additionally, Cohen's d was computed to quantify the magnitude of the gain scores.

Third, the students' perceptions of the implemented activities were analyzed using thematic analysis. The thematic analysis of the FGD responses and journal entries followed the coding process: (1) initial open coding by identifying meaningful segments of the dataset, (2) comparing codes and grouping into categories, and (3) developing higher-order themes. Two coders independently implemented the coding process. To establish a common understanding and interpretation of the coding scheme, the coders conducted a pilot coding of the responses recorded in the first FGD, including the students' journal entries. Then, the coders applied the coding scheme to the entire dataset. After the first round of coding, a 29% agreement was reached. Iterative discussions ensued to resolve discrepancies. During these discussions, the third author was needed to confirm the codes based on his classroom observations. After several discussions and revisions, the codes achieved a 73% agreement. Accordingly, a percentage agreement of at least 70% indicates substantial agreement between coders (Hallgren, 2012).

RESULT

A. Development of the RME-bIM Activities

The development of RME-bIM followed the modified R&D stages of Borg and Gall. As presented in Figure 1, R&D involved five main stages: analysis, planning, product development, evaluation and revision, and field testing.

1. Analysis Stage

In the initial stage of the development process, the researchers conducted a comprehensive analysis of achievement test scores and instructional needs. Specifically, they examined the Quarter 4 achievement test results for Grade 8 students at the participating school for the Academic Years 2021-2022, 2022-2023, and 2023-2024. The results revealed a consistent pattern of low performance in Probability-related competencies, with an average score of only 38%. This significant gap in student understanding served as the basis for selecting probability-related competencies as the focus of the instructional intervention. These competencies were identified from the Philippine K-12 Mathematics Most Essential Learning Competencies (MELCs). Table 1 presents the specific competencies addressed in the developed RME-bIM.

Parallel with the curriculum analysis, the researchers reviewed suitable tools for designing IM materials. After evaluating several options, the researchers chose the PowerPoint application as the primary development platform, specifically utilizing its Visual Basic for Applications (VBA) capabilities to enable interactivity. This decision is consistent with the findings of Nugroho et al. (2022), demonstrating the effectiveness and validity of using PowerPoint with VBA in designing IM for mathematics instruction. The choice of this tool ensured both accessibility and functionality, a practical option for classroom integration.

Table 1. Learning competencies identified from the DepEd K-12 mathematics curriculum

Quarter	Content	LC Code	Learning Competency (LC)
4	Probability	M8GE-IVf-1	illustrates an experiment, outcome, sample space, and event
		M8GE-IVf-g-1	counts the number of occurrences of an outcome in an experiment: (a) table; (b) tree diagram; (c) systematic listing; and (d) fundamental counting principle
		M8GE-IVh-1	finds the probability of a simple event.

2. Planning Stage

The researchers focused on aligning IM features with the principles of RME. Key elements of IM were identified, including digital components that support active student engagement and self-paced exploration. The mathematics competencies identified in the analysis phase were translated into specific interactive elements using PowerPoint enhanced with VBA to operationalize the plan. Table 2 presents sample interactive features with VBA requirements for every identified competency.

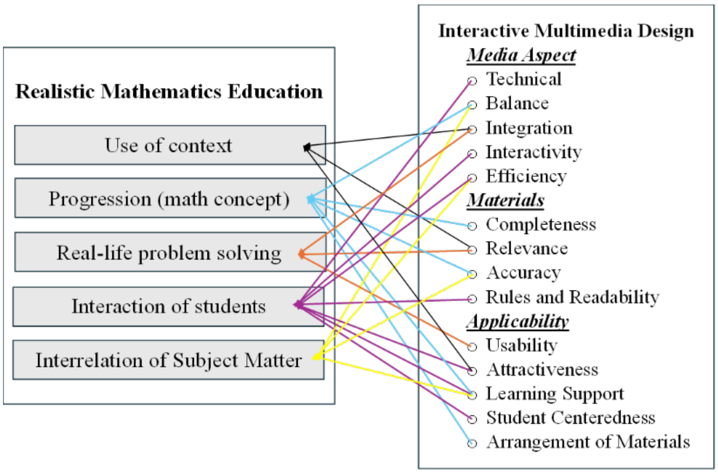
Table 2 Sample interactive feature with digital tool requirements

LC Code	Sample Activity	Description	Interactive Feature	VBA functionality
M8GE-IVf-1	Dice Roll Demo	Click buttons to animate sample spaces and events.	Animated simulations of experiments	VBA-triggered animations and object visibility controls
M8GE-IVf-g-1	Snacks Combination	Move pictures of local snacks to illustrate counting methods.	Interactive tree diagrams, auto-generated tables, drag-and-drop tasks	VBA loops to auto-populate tables and generate trees
M8GE-IVh-1	Probabili-Quizzes	Engage in contextual problem-solving tasks.	Guided problem-solving, input-response, and scoring mechanism	VBA conditional logic to give instant feedback; VBA variables to store scores

3. Development of Preliminary Product Stage

The principles of RME and the features of IM learning were two major foundations that guided the development of the preliminary version of the instructional activities. The design integrated RME indicators using relevant contexts, learning progression, real-life problem-solving, student interaction opportunities, and subject-matter interrelations (Wahyudi et al., 2017; Hikayat et al., 2020). The activities combined IM elements such as user control, interactivity, feedback, and audiovisual integration to deliver the RME goals (Septiani et al., 2020; Ratnasari et al., 2021). Figure 2 illustrates the mapping of RME elements with IM indicators. For instance, it can be seen in the mapping that "learning progression", as an RME indicator, can be delivered through the balanced use of media aspects with complete, organized, and accurate resource materials that serve as appropriate learning support.By persistently assessing current needs and challenges, Hasan champions a curriculum that is not only responsive but also relevant, thereby ensuring that education serves as a potent instrument for societal advancement and transformation. This perspective invites educators and policymakers alike to engage in a reflective practice that prioritizes adaptability, fostering an educational landscape that is both inclusive and effective in addressing the complexities of modern life.

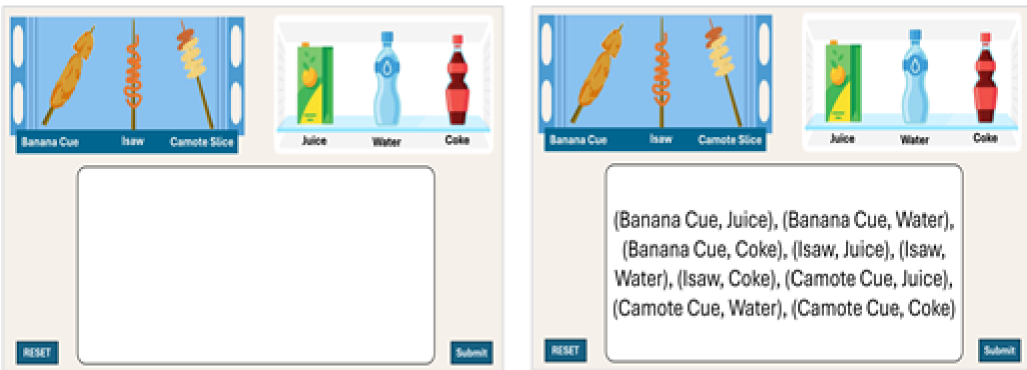
Figure 2 Mapping of RME with appropriate IM indicators



The researchers developed activities for each identified mathematics learning competency. Each activity was designed to provide opportunities for active manipulation, allowing students to interact with the content through simulations, input fields, and guided tasks. This interactivity aimed to support engagement and conceptual understanding through immediate feedback and contextualized exploration (Etyarisky & Marsigit, 2022).

For instance, Figure 3 presents a sample RME-bIM activity named "Snacks Combination." The product is an interactive activity that allows students to move and drag pictures of local snacks. Each time a pair of snacks is selected, the list in the empty white box automatically updates with the name of the chosen pair. This activity addressed the concept of "counting through systematic listing." This activity also allows students to visualize that repeated choice is counted only once in the list of possible outcomes.

Figure 3 Sample RME-bIM activity in the methods of counting possible outcomes



(a) The user interface of the "Snacks Combination" activity

(b) The list is updated as students choose pair of local snacks

To illustrate how VBA was used in the activity above, Figure 4 shows a brief snippet of the code. Specifically, this section serves as the error-catching condition that is necessary for the activity to succeed. These lines execute after clicking the "submit" button shown in Figure 3. This part ensures that the user selects an item from both the food and drinks categories. Otherwise, the activity displays a message box that says, "Please select one item from each group before submitting." This part is essential to guide students on the actions to consider while engaging in the activity.

Figure 4 Portion of VBA code utilized in "Snacks Combination" activity

```
' Initialize names if not already done
InitializeNames

' Check if both selections have been made
If currentGroup1Selection = 0 Or currentGroup2Selection = 0 Then
    MsgBox "Please select one item from each group before submitting."
    Exit Sub
End If

Set CurrentSlide = ActivePresentation.Slides(1)
Set AnswerShape = CurrentSlide.Shapes("Answer")
```

4. Evaluation Stage

A panel of three evaluators, each holding a PhD and possessing expertise in mathematics content, pedagogy, and educational technology, reviewed the preliminary RME-bIM activities using the RAET. Given the limited number of evaluators, qualitative comments are critical to strengthening the content validity of the activities. Thus, both quantitative ratings and qualitative feedback were considered to ensure reliable evaluation of the activities.

First, the panel assessed multimedia aspects, particularly media elements, materials quality, and usability. The results indicated "Strong Agreement" across all criteria, with mean ratings of 3.52 for media quality, 3.67 for instructional materials, and 3.58 for usability. These findings align with the validation results reported by Suhartati et al. (2024), confirming that the developed activities effectively embody the essential elements of IM.

Second, the same panel evaluated the activities' conformity to RME characteristics, including the use of context, learning progression, real-life problem-solving, student interaction, and interrelation of subject matter. The ratings revealed "Strong Agreement" across all characteristics, with a mean rating of 3.89 for the use of context, 3.78 for learning progression, 3.67 for real-life problem-solving, 3.56 for student interaction, and 3.67 for the interrelation of subject matter. These results demonstrate that the developed activities exhibited RME principles.

Overall, both the quantitative ratings and the evaluators' expert qualitative feedback indicated that only minor revisions were required. Guided by these comments, the researchers improved navigation prompts, clarified instructions, enhanced feedback messages, and refined multimedia elements to strengthen usability and clarity before proceeding to field testing.

5. Field Testing Stage

Before full-scale implementation, the revised RME-bIM activities underwent a preliminary field test with a different group of 37 Grade 8 students. The primary aim of this stage was to gather the initial perceptions of the target learners on the usability, pedagogical value, and overall appeal of the developed activities. Participants during this stage responded to the FTPQ. The results, summarized in Table 3, revealed that students were "very satisfied" across all dimensions. These include content quality, teaching and learning capacity, support capacity, assessment and feedback, and overall satisfaction. The high ratings indicate that learners found the RME-bIM activities clear, engaging, and potentially effective in facilitating their understanding of probability concepts.

Table 3. Students' initial perception of the developed RME-bIM

Perception Criteria	Mean Rating	Interpretation
Content	3.46	Very Satisfied
Teaching and Learning Capacity	3.62	Very Satisfied
Support Capacity	3.40	Very Satisfied
Assessment and Feedback	3.45	Very Satisfied
Overall Satisfaction	3.53	Very Satisfied

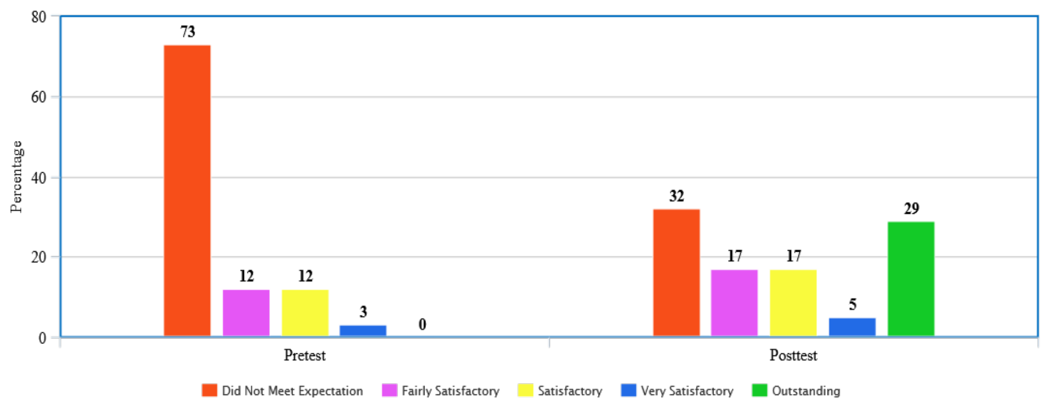
Note: 1.00-1.75 – "very dissatisfied"; 1.76-2.50 – "dissatisfied"; 2.51-3.25 – "satisfied"; and 3.26-4.00 – "very satisfied"

Overall, the field test outcomes provided evidence of the acceptability of the developed activities for Grade 8 students. The results justify the activities' validity for the final implementation phase. Furthermore, the feedback and observations obtained during this stage served as the basis for the final revisions of the activities.

B. Improvement of Students' Performance in Mathematics with RME-bIM Activities

The implementation of the RME-bIM activities resulted in a notable improvement in students' performance in Mathematics, particularly in probability concepts. As shown in Figure 5, the majority of students' proficiency levels during the pretest were "Did Not Meet Expectation" (73%), with very few students classified as "Fairly Satisfactory" (12%), "Satisfactory" (12%), and "Very Satisfactory" (3%). Notably, no student achieved an "Outstanding" level prior to implementation.

Figure 5. Summary of students' proficiency levels before and after intervention



After implementing the RME-bIM activities, posttest results showed a marked improvement: 29% of students had already achieved "Outstanding," and the number in the "Did Not Meet Expectation" group decreased to 32%. Additionally, the number of students at other proficiency levels increased slightly, including "Fairly Satisfactory" (17%), "Satisfactory" (17%), and "Very Satisfactory" (5%). This result suggests that a substantial proportion of students who did not meet the expected level of proficiency prior to implementation improved to higher levels. Levels other than "Did Not Meet Expectations" under DepEd's standards indicate passing grades. This descriptive trend indicates that the implemented activities helped students improve their understanding of probability concepts. It reflects that the developed materials were accessible to learners across varying levels of proficiency.

Moreover, the result of the one-tailed paired t-test further indicated the significant improvement in students' achievement. Table 4 reveals that the increase in the mean score from the pretest to the posttest is statistically significant (t = 6.42; p < .001). This result confirms that students performed significantly better after engaging in the developed RME-bIM activities.

Table 4. Result of one-tailed paired t-test analysis of pretest and posttest scores

Group	Mean	SD	t-value	df	p-value	Cohen's d
Pretest	13.12	2.89	6.42	40	p < .001	1.002
Posttest	9.49	4.14				

H1: The increase in the mean scores from pretest to posttest is significant.

The coefficient d further quantified the effect of implementing the RME-bIM activities. Since the value of d is greater than .80, the effect of the activities is considered "large" (Cohen, 2009). This effect size indicates that implementing the activities produced a substantial improvement in students' test scores. Furthermore, the significant improvement underscores the activities' potential to facilitate learning gains.

C. Students' Perception of the RME-bIM Activities

To examine students' perceptions of the implementation of RME-bIM activities, a thematic analysis was conducted on students' responses from FGDs and journal entries. Table 5 presents the generated subthemes, codes, and sample statements related to students' perceptions. As shown in the table, the implementation of the activities fostered students' personal beliefs, positive mindset, inquiry learning, authentic learning, and mathematical understanding.

Table 5. Generated subthemes, codes, and sample statements related to students' perception of the implementation of the activities

Sample Citation	Code	Subtheme	Theme
[S31] "Once you click [the options], the animations are very interesting. I like to participate in these activities since it seems that I am just playing with my phone."	increases motivation and engagement	Personal Beliefs	Students' positive perception of the RME-bIM activities
[S6] "I enjoy these activities because I can interact with the pictures. We have control over what we want to do."	enjoyable		
[S34] "I think I am now more confident to answer questions [in exercises] since I feel I understood well what probability is."	promotes self-efficacy		
[S2] "I hate math[ematics] but I appreciate [the activities]. I realize that learning the subject is not only for the sake of grades, but it also has [practical] significance."	develops appreciation of the subject	Positive Mindset	
[S8] "...I find it difficult to understand math. I could not cope with [purely] discussions. At least these [type of] activities really illustrate what is meant by 'sample space' for instance."	reduce anxiety		
[S27] "[Participating in the class] is not a burden since I feel like [the activities] can be likened to a game."	encourages active participation	Inquiry Learning	
[S15] "You can try other choices [while doing the activities], to explore on other possible outcomes."	supports exploration		

[S13] "I think I can now solve problems [related to probability] more efficiently since I can visualize how the different techniques work."	reinforces problem understanding	
[S24] "The examples are also nice because they are familiar to us. They are easy to understand."	real-life relevant	Authentic Learning
[S29] "The activities are amazing in a way that I realize the application of probability in [real] life."	supports meaningful learning	
[S16] "I like it because [you know] we can really understand what probability means [referring to related concepts]. When I click on something, it kind of illustrates what Sir just discussed."	promotes conceptual understanding	Mathematical Understanding
[S4] "It helped me recall efficiently the different techniques [referring to counting] since the examples really showed them how."	enhances retention	

The subtheme "personal beliefs" emerged from codes related to increased motivation and engagement, enjoyment of the activities, and a sense of self-efficacy. During the implementation, students demonstrated heightened attention and active involvement, as evidenced by their eagerness to participate in simulations and respond to on-screen prompts. Students' responses reflected related experiences. Some of their recurring responses described the activities as "maka-lingaw" (enjoyable) and "mas ganahan ko ani" (I prefer these [activities]). These phrases make it evident that students perceived the activities as enjoyable. In addition, several students reflected on how their learning from the activities helped them in solving exercises and tasks related to probability, as evidenced by S34. This finding suggests that RME-bIM activities may promote self-efficacy. Collectively, these patterns illustrate how students' experiences with the activities helped shape their beliefs about their personal capacity and the importance of appropriate learning activities.

The subtheme "positive mindset" arose from codes describing students' growing appreciation of the subject and reduced anxiety during lessons. It was observed during the implementation that students participated in the class activities with few signs of hesitation. For instance, they became more willing to attempt answers and explore options within the activities' interface. During FGDs, several students noted that the lessons felt "dili kaayo pressure" (relieved of pressure) or "mas dali masabtan ang topic" (easier to understand), which reflected a reduction in anxiety in mathematics. Other notable responses explicitly expressed appreciation of the subjects, such as "naa jud diay gamit ang math" (math [referring to probability] is indeed practical) or "mas ganahan ko'g ingon-ani nga math" (I like math more like this). These recurring expressions across the data sources formed a coherent cluster, suggesting a positive mindset.

The "inquiry learning" subtheme was informed by codes demonstrating active participation, exploration, and reinforced understanding of problems. The students acknowledged that the RME-bIM activities enabled them to participate actively in interactive simulations. For instance, S27 compared their level of participation to playing games. Accordingly, the activities were notable deviations from the ordinary lectures they were accustomed to attending. During the activities, students had opportunities to explore the concept of probability by interacting with the RME-bIM activities. This observation was confirmed by S15, who described the different choices they can make to visualize the concept. The interactive aspects also enabled students to gain a clear understanding of probability-related problems. Moreover, the activities enabled students to apply their understanding in problem exercises as described by S13. These characteristics described by the students, suggest that the implementation of RME-bIM activities encouraged an inquiry-based learning environment.

The subtheme "authentic learning" was related to codes indicating that the activities were real-life relevant and supportive of meaningful learning. Most students shared their observations about the types of contexts and examples used in the activities. One of the most frequent responses identified across FGDs and journal entries is the description of the activity context as "common." This description apparently reflects how students view the activities as relevant to real-life situations. Moreover, because of the nature of the activities, many students shared their realization about the role of mathematics in daily life. For example, S29's statement suggests how the activities demonstrated the practical application of probability. The consistent appearance of these codes hinted that authentic learning is promoted through RME-bIM activities.

Finally, the subtheme "mathematical understanding" emerged from codes highlighting conceptual understanding and enhanced retention. S16 shared that the activities provided a compelling visualization of the different concepts related to probability. The same sentiment was expressed by many of the students in their journal entries. Evidently, this appreciation suggests that the RME-bIM activities were effective in promoting the students' conceptual understanding. Additionally, students claimed that this aspect of the activities helped them recall the concept more easily. S4 agreed to this claim, describing how the visuals of the activities helped him efficiently recall the different counting techniques used to determine the sample space. These codes indicate that implementing the activities enhanced students' mathematical understanding.

DISCUSSION

The findings of this study provide strong evidence supporting that RME-bIM activities had an impact on students' mathematics performance, engagement, and perception of learning. Given the integrated principles of RME and IM, students gained a better understanding of probability through simulations, context-based tasks, and student-centered exploration (Patullayeva, 2022; Westomi et al., 2024). These activities helped students develop a cognitive schema for relevant concepts (Kuzmak, 2016). The dynamic visualizations, such as event animations and the logical progression of steps, enabled learners to observe mathematical processes that are typically abstract and complex. This aspect aligned well with the need to bridge learning from the concrete to the formal level – one of RME's central tenets (Zubainur et al., 2020). Hence, interactive, visually enriched, and contextually grounded learning environments fostered improvements in students' understanding.

The use of real-world context grounded students' understanding and allowed them to view mathematics as knowledge that could be visualized and manipulated (Rubel & McCloskey, 2021). Through the RME framework, the students constructed mathematical ideas by working on contextual problems (Susanti, 2025). It allowed them to reinvent representations and discover mathematical relationships on their own. This scheme was crucial in enabling students to take ownership of their learning (Koerunnisa et al., 2024). Accordingly, meaningful learning is achieved when students take ownership and recognize the relevance of learning in their individual lives (Khatter et al., 2024). Within the short span of this study, the students exhibited these characteristics, resulting in a significant improvement in their performance. This result aligns with previous studies that assert RME enhances conceptual understanding by providing a link between mathematical ideas and life-like situations (Laurens et al., 2017; Dinglasan et al., 2023).

Several IM features proved to be impactful on students' performance. First, the balanced and efficient media aspect, facilitated through interactive visual animation, enhanced the understanding of the complex interrelationships of the subject matter (Mayer, 2014; Hadi et al., 2022). It strengthened the connection between students' personal experience and abstraction. Second, the accurate materials and the rule on immediate feedback provided students with the opportunity to refine their reasoning in real time. Ajogbeje (2023) argues that immediate feedback is a critical component of learning. It helps students bridge the gap between their current performance levels and their desired goals. Third, self-controlled pacing empowered students to revisit content independently. It helped them set the dynamics of learning at their own pace. This mechanism supported self-regulation and increased students' confidence in handling mathematical tasks (Suri & Rachmadtullah, 2021). Subsequently, these IM elements increased students' comprehension.

Consistent with Aytekin-Uskun et al. (2021), the findings signify that RME-bIM activities had an impact on students' performance. The impact is attributed to the coherence of the RME and IM frameworks. Separate studies provided evidence that RME and IM increase students' performance. In particular, Nurmawati et al. (2020) emphasized how RME facilitates conceptual understanding by anchoring mathematical ideas in real-life contexts. On the other hand, Aytekin-Uskun (2021) highlighted that IM enhances engagement and cognitive processing by allowing learners to actively manipulate visual and auditory information. Taken together, RME lays the framework for designing the activities, while IM design provides the means for achieving it (Fredy et al., 2020; Beswick et al., 2023). The interaction of the two frameworks operationalized the constructivist learning environment. Evidently, the RME-bIM activities catered to students' active participation in knowledge construction.

Beyond cognitive gains, the implementation of the RME-bIM activities yielded affective benefits. From the students' perspective, the nature of the activities, which allowed for interactive exploration and real-life relevance, was cited as a reason for reduced anxiety and fostered an appreciation of the subject. Relevant literature considers these factors to be barriers that interfere with attention, task interest, and working memory (Olmez & Ozel, 2012; Dowker & Sheridan, 2022). When anxiety is reduced, students become more open to exploration and are less likely to fear making errors. Similarly, developing an appreciation for mathematics fosters a positive orientation toward mathematical problem-solving tasks. These affective gains were achieved through the implementation of these activities (Bray & Tangney, 2016).

In turn, the affective improvements contributed to stronger conceptual understanding. This claim is supported by studies showing that personal beliefs and a positive mindset affect how students make sense of the information presented to them (Blazanin et al., 2025). In hindsight, the RME-bIM activities allowed reflecting on outcomes, comparing possible scenarios, and making sense of mathematical symbols without the pressure of high-stakes correctness. When students are emotionally empowered, they are more likely to engage in deeper and more meaningful processing. This is a critical condition for conceptual learning and long-term retention. In this sense, the affective benefits of the RME-bIM activities strengthened students' capacity to construct and internalize mathematical ideas (Angraini & Fitri, 2023; Gübbük & Uygun, 2024).

CONCLUSION

This study developed, validated, and implemented RME-bIM activities to enhance the mathematics performance of Grade 8 students. Grounded in the principles of RME and IM design, the developed activities exhibited strong validity and acceptability, as confirmed by the panel of evaluators. The core element of the developed activities is the integration of context-rich problems, simulation-based interactivity, and student-centered tasks. This design aligns with the framework laid out by the DepEd K to 12 programs, particularly the initiative to use innovative technologies.

This study also demonstrated the positive benefits of the developed RME-bIM activities in promoting students' mathematics performance. This result contributes to improving mathematics instruction by providing a practical option for effective multimedia integration in the classroom. It provides a concrete template for maximizing familiar digital tools, such as VBA in PowerPoint, to implement IM materials and RME principles in cooperation. Further, this study highlighted two relevant pedagogical techniques: (i) RME can be effectively delivered in the classroom using innovative digital learning tools, and (ii) IM materials can be designed within the realm of the RME framework.

However, the researchers acknowledge several limitations. First, this study employed a single intact class without a comparison or control group. Although improvements were observed in students' performance, the absence of a control group may limit the ability to make strong causal claims about the effectiveness of the RME-bIM activities. Second, the study used the same set of test items for both the pretest and posttest. Repeated exposure to identical items may have introduced testing effects that could inflate posttest scores. Third, the implementation period lasted only two weeks. This timespan may be insufficient to capture the sustained influence of the RME-bIM activities on students' learning outcomes.

To address these issues, future studies may consider the ensuing recommendations. First, a quasi-experimental design may be implemented, including a control group, to strengthen causal inference. Second, parallel forms of pretest and posttest achievement tests may be employed to minimize familiarity effects. Third, a longer implementation period may be used to examine retention and sustained learning outcomes.

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