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Development of Student Worksheets Integrated with Microlearning Comics for Learning Probability

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Abstract

Numerous studies have shown that students face difficulties in learning probability. This study aimed to enhance students' understanding of the concept of probability while developing their reasoning skills by integrating comics into student worksheets. It focused on designing probability material for grade 10 using the student worksheets and microlearning (comics) that were both effective and efficient. The material was developed using *Pendidikan Matematika Realistik Indonesia* (PMRI) approach, incorporating a microlearning method within the context of culinary tourism, to enhance students' understanding of probability and reasoning skills. This study employed a design research methodology in two stages, namely preliminary study and formative evaluation. The subjects of this study were 34 students of grade tenth at Senior High School in Prabumulih. Data collected through observations, tests, and interviews were analyzed descriptively. The study resulted the student worksheets on probability, which were incorporated with microlearning comics whose effectiveness and efficiency were aligned with the characteristics of the PMRI approach. Based on the findings, it can be concluded that the PMRI-based student worksheets that were incorporated with microlearning comics were efficient and effective in helping students develop their reasoning skills. The integration of comics and the PMRI approach reflects a commitment to innovation and the continuous development of effective learning designs that promote inclusive, equitable, and meaningful learning experiences.

Keywords: Comics, Education in Developing, Microlearning, Probability, Reasoning Skills

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INTRODUCTION

Probability is a mathematical concept concerning the likelihood of an event occurring and serving as a tool for making predictions or decisions (Groove, 2018). It is also recognized as a mathematical discipline focused on determining the chances of specific random events taking place (Greenwood et al., 2011). It serves as the basis for predicting how likely something is to happen. A good understanding of probability allows students to identify events that arise from a random experiment. To learn probability, it is essential that students develop reasoning skills.

However, while probability forms a fundamental part of mathematical thinking, its abstract nature poses learning challenges for many students. Despite its importance and wide application, mastering probability is not without challenges. Many students find the topic difficult due to its abstract nature and the reasoning it requires. This difficulty is reflected in several studies that highlight the persistent problems students encounter when learning probability. Armiati et al. (2022) highlighted that students often struggle because they rely on memorized formulas and follow predetermined solution patterns provided by the teacher without fully grasping the underlying concepts. Arican & Kuzu (2019) identified common mistakes in probability learning, particularly in distinguishing between independent and dependent events and in calculating their probabilities. In line with this, Astuti et al. (2020), pointed

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out that misconceptions in solving probability problems frequently involve misinterpretations of questions. These errors often stem from a lack of conceptual understanding of probability, with students mainly making theoretical mistakes while having limited awareness of interpretation errors (Álvarez et al., 2024).

In response to these persistent learning difficulties, it becomes increasingly important to shift the focus from procedural to conceptual learning in probability. One key aspect of this shift is helping students strengthen their reasoning abilities, which play a crucial role in interpreting and solving probability problems. To determine the sample space of an experiment, students must rely on their reasoning skills rather than memorized formulas. Students need to estimate the probability of an event. As stated by Sharna et al. (2021), every event always involves an assessment of how likely it is to occur, or perhaps not to occur. Thus, teachers should support students in understanding the concept of probability while fostering their reasoning skills. Since reasoning skills are essential for understanding probability, teachers need to emphasize conceptual learning rather than rote memorization to enhance students' logical thinking.

Nevertheless, strengthening students' reasoning cannot rely solely on instructional methods, it also requires appropriate and engaging learning materials. Students' difficulties in learning are not solely due to individual challenges but also result from insufficient teaching materials. Research findings indicate that teachers primarily rely on school-provided textbooks, without additional supporting resources. Hiltrimartin et al. (2022) observed that student worksheets primarily emphasize formulas and provide material summaries without incorporating real-life contexts. Furthermore, the exercises lack connections to practical problems, making them less effective in encouraging students to engage in problem-solving. Similarly, Batanero & Álvarez (2024) stated that most mathematics books only present subject matters as interesting objects without exploring deeper understanding of concepts and their applications.

The consequences of these instructional limitations are reflected in international assessments. Those learning challenges are in line with the decline in Indonesia's mathematical performance in PISA 2022. While Indonesia's ranking improved compared to 2018, the mathematics score dropped by 13 points internationally (OECD, 2023). This decline caused a significant concern, as PISA results are widely used to assess the quality of mathematics education (Wijaya et al., 2024). In the Independent Curriculum, probability is taught at stage E (grade 10), where students must explain probability, analyze compound events, and determine the probabilities of independent events (BSKAP, 2024). Greenwood et al. (2011) defined a sample space as encompassing all possible outcomes of an experiment. Since each outcome represents a potential result, understanding the concept of sample space is essential for students when analyzing random experiments and related events. Since probability is part of PISA's uncertainty and data domain, students require strong reasoning skills to effectively grasp its concept.

To address the instructional gaps and improve conceptual understanding, effective learning strategies should incorporate appropriate media and contextual approaches. One effective way to

enhance learning is by integrating media and instructional methods that provide contextual understanding. Utilizing learning media allows teachers to present mathematical concepts to students more effectively. To ensure information is absorbed efficiently, materials should be broken down into smaller, manageable segments, making them easier to understand and retain. Microlearning media are effective tools for delivering concise and easily accessible information. Microlearning is an approach centered on key concepts, employing multisensory and multimodal strategies within a short and focused time frame to enhance learning objectiveness (Dolasinski & Reynolds, 2020).

Microlearning not only aids in knowledge retention but also strengthens conceptual connections. It facilitates-connections between different topics and ideas during the learning process (Aldosemani, 2019; McNeill & Fitch, 2023). Additionally, it enhances students' focus, concentration, and ability to retain knowledge more effectively. By structuring materials into small, meaningful sections, microlearning aligns with cognitive load theory, facilitating conceptual learning on probability. In this study, microlearning was used as an underlying principle for developing comics as learning media. Students engaged with the microlearning medium, which was incorporated into a student worksheet to enhance their reasoning skills.

In Indonesia, Zulkardi et al. (2020) introduced *Pendidikan Matematika Realistik Indonesia* (PMRI) an instructional approach specifically designed for teaching mathematics, which was adapted from Realistic Mathematics Education (RME). Several studies have implemented the PMRI approach in probability learning, utilizing various contexts, such as sudoku and snakes and ladders (Wijaya et al., 2021), snakes and ladders (Sari et al., 2022), dice (Armiati et al., 2022), maritime contexts (Malalina et al., 2024). These contexts were integrated into student worksheets, incorporating images accompanied by detailed explanatory texts. In this study, the researchers applied the context of culinary tourism in Prabumulih City, embedding it into a microlearning medium that was integrated into a student worksheet, as previously described.

While previous studies have explored context integration, most have presented probability through photographs and brief explanations, with limited emphasis on deep conceptual learning. This study introduces comics as a microlearning medium, integrating it into a student worksheet for discussion-based learning. This approach was expected to enhance collaboration and reasoning development, allowing students to engage with the probability concept interactively. Based on the issues outlined, this study sought to answer the research question about how effective the student worksheets were in enhancing students' reasoning ability.

Beyond its immediate instructional goals, this research aligns with global educational priorities. This research contributes to the achievement of Sustainable Development Goal 4 (SDG 4), which aims to promote inclusive, equitable, and quality education, as well as lifelong learning opportunities for all. By developing student worksheets integrated with microlearning comics in probability learning, the study aims to enhance students' mathematical fluency, increase participation, and promote greater inclusivity within heterogeneous classroom settings. The integration of visual storytelling and

segmented content facilitates accessible learning experiences, particularly for students with varied cognitive and literacy levels. Furthermore, this innovative approach reflects a commitment to creating engaging educational resources that address diverse student needs and support more equitable outcomes in mathematics education.

METHODS

This study employed a design research methodology within the framework of development studies. With the objective of designing and validating the student worksheets on probability that was integrated with microlearning (comics). The study aimed to develop a probability material by creating instructional resources based on the PMRI approach, utilizing a microlearning medium as an educational innovation. This aligns with one of the key principles of design research, which emphasizes innovative educational practices (Bakker, 2019). As part of the validation process, this study also assessed the effectiveness of the microlearning medium in improving students' understanding of probability and reasoning skills. The development process followed two main stages: preliminary evaluation, which included initial analysis and design, and formative evaluation, which involved iterative testing and refinement (Tessmer, 1993; Zulkardi, 2002), This sequence of stages is illustrated in Figure 1.

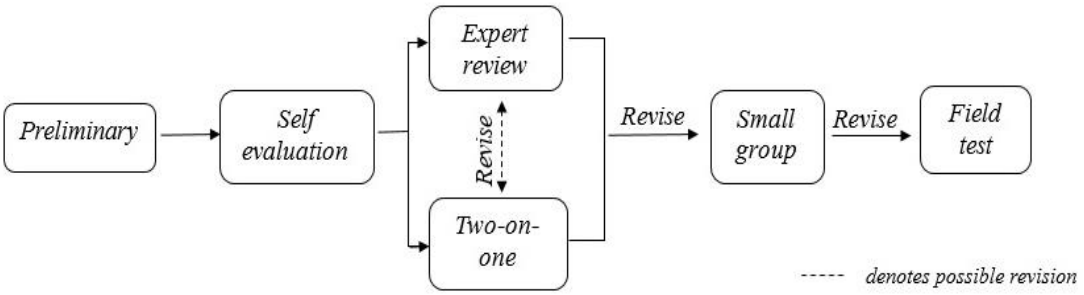


Figure 1. Research flow

Figure 1 illustrates the research flow in this study. The preliminary evaluation phase involved analyzing the curriculum, probability theory, and characteristics of students, followed by the development of the learning material. The formative assessment phase focused on the prototyping process, which included expert review, two-on-one evaluation, small-group evaluation, and field test evaluation. This study was conducted with 34 grade 10 students from SMAN 6 Prabumulih as participants.

Preliminary Study

During the preliminary study, the researchers identified existing issues within probability material in grade 10 that were relevant to the educational context. This was done through a review of

literature, previous studies, probability theories, and relevant books. Additionally, the researchers analyzed the curriculum related to probability, defined learning objectives to enhance achievement, and explored culinary tourism in Prabumulih City as a contextual framework for the learning material. Contextual learning is a key characteristic of the PMRI approach. In this approach, real life contexts relevant to students may be incorporated into teaching materials (Zulkardi & Putri, 2020). For instance, by integrating culinary tourism as a learning context, students are encouraged to grasp probability concepts while simultaneously strengthening their reasoning skills, resulting in a more meaningful mathematics learning experience.

After completing the analysis, the researchers conducted a diagnostic assessment of students, particularly those who were the subjects of this study, to identify their characteristics in phase E (grade 10). The diagnostic assessment was carried out through observations during classroom instructions, allowing the researchers to predict students' abilities and use this information to design a probability teaching material that would be aligned with their characteristics, ensuring a high-quality learning experience. This is consistent with Waheed et al. (2023) statement, that data obtained from instructional processes can be utilized to improve the effectiveness of education. Finally, the researchers began developing a worksheet as a learning material, integrated with a microlearning medium in the form of comics. The worksheet function provided a space for discussion and collaboration among students, while the microlearning medium served as the primary instructional material, which was broken down into small, manageable segments for easier comprehension.

Formative Evaluation

In formative evaluation, the researchers conducted five phases: self-evaluation, expert review, one-to-two evaluation, small-group evaluation, and field test. In the self-evaluation phase, the researchers independently assessed the prototype worksheet integrated with microlearning comics developed during the preliminary study. This process involved discussions with supervisors and model teacher, resulting in Prototype 1, which was refined to address identified weaknesses.

During the expert review phase, Prototype 1 underwent a comprehensive evaluation process conducted by both media and content experts. The media experts, representing Southeast Asian Ministers of Education Organization Regional Open Learning Centre (SEAMEO SEAMOLEC), were responsible for assessing the visual and technical aspects of the learning media, including the layout, readability, and overall design quality of the worksheet integrated with microlearning comics. Meanwhile, the content experts, who were affiliated with SEAMEO QITEP in Mathematics (Centre for Quality Improvement of Teachers and Education Personnel in Mathematics) and *Balai Besar Guru Penggerak* Daerah Istimewa Yogyakarta (BBGP DIY), evaluated the accuracy, clarity, and pedagogical relevance of the mathematical content, particularly related to the topic of probability. Their feedback contributed to the revision and improvement of the prototype prior to broader testing.

The one-to-two evaluation involved two Grade 10 students working with Prototype 1. The researchers observed their interactions with the material and conducted interviews using open-ended questions to explore its strengths, limitations, and any learning difficulties. These insights guided the development of Prototype 2. In the small-group evaluation, Prototype 2 was tested with 15 students divided into four groups to simulate a classroom context. This phase aimed to evaluate the prototype's instructional effectiveness and efficiency on a limited scale, enhancing confidence in its implementation.

In the field test evaluation, Prototype 2, which was declared valid and efficient, was tested on 34 grade 10 students at SMAN 6 Prabumulih. Students were divided into 12 groups, each consisting of three students, except for one group, which consisted of four students. At this stage, the researchers observed how the students worked on the worksheet that was integrated with microlearning comics to evaluate its effectiveness in relation to students' reasoning abilities. Additionally, the researchers employed a model teacher as an instructor in delivering probability materials. The model teacher was an actual class teacher. Meanwhile, the researchers acted as an observer during the evaluation, determining how well the model teacher and students utilized the instructional material. This is consistent with the goal of a field test evaluation according (Tessmer, 1993), which is to evaluate the effectiveness of the instruction. At this stage, the instruction was presented in its best form, although revisions were still possible.

Data analysis was conducted to evaluate both the effectiveness and efficiency of the worksheet that was integrated with microlearning comics. The researchers established a scoring range for the pre-test and post-test results, as shown in Table 1. These scores were then compared to determine the extent of students' improvement in understanding the concept of probability. In this way, the researchers could identify the appropriate follow-up actions for students.

Table 1. Assessment score

Interval	Category
86 - 100	Excellent
71 – 85,99	Good
56 – 70,99	Satisfactory
40 – 55,99	Poor
< 40	Very poor

As can be seen in Table 1, there were five assessment categories that the researchers implemented according to the range in which the score of each student's fells. Each category represented a different level of student performance, allowing for a more detailed analysis of student understanding. This classification provided a guide for the researchers to identify specific areas where students might need additional support or intervention.

RESULTS AND DISCUSSION

Preliminary Study

During the preliminary study, the researchers formulated learning objectives aligned with the learning outcomes laid down in the Independent Curriculum: (1) students identifying the sample space of a random experiment; (2) students determining the number of elements in an event across various situations; and (3) students calculating the probability of a compound event. Next, the researchers developed Prototype 1, which consisted of two activities in the student worksheet Before that, educational comics was created as a microlearning medium containing a learning material about sample space. The comics was integrated into the student worksheets to constitute the first activity. In the second activity, students determined the probabilities of events under guidance.

The comics featured a culinary tourism theme set in Prabumulih City. The storyline was about two girls who visited a souvenir center in Prabumulih city (Figure 2). To further engage students, the comics integrated a real-life mathematical scenario related to probability, enabling them to apply concepts in a relatable context. Additionally, the visuals and dialogs were designed in such way to enhance comprehension and foster an enjoyable learning experience.

Figure 2. The comics' design

As shown in Figure 2, the comics depicted two girls choosing one item out of for available items in a menu randomly. However, because one of them was to treat the other to a different item than that chosen by the other, two different items of the four available items in the menu were to be selected. The final comic product can be seen at Comics_1. The content of the comics focused on the concept of sample space in an experiment where various menu items could be randomly selected from four available options. Using real-world context in comics could help students focus on a single source of information (Lam et al., 2023). Enhancing their understanding of the subject matter.

Formative Evaluation

Expert Review

In the expert review phase, Prototype 1 was evaluated by media and content experts to identify its strengths and weaknesses. Media validation was conducted by instructors from SEAMEO SEAMOLEC, while content validation involved experts from SEAMEO QITEP in Mathematics and BBGP DIY. In this stage, several components were reviewed (Table 2). The feedback provided by these experts was used as a crucial guide in refining the prototype and enhancing its overall quality.

Table 2. Summary of the results of the expert review of the comics

Categories	Comment
Developing a structured framework for objectives	It is suitable
Content of the comics	Explanations and reinforcement are necessary to ensuring that the details in the student worksheets are properly linked to the concept of sample.
Illustrations of the comics	Properly fitting
Template design theme	Quite clear
Harmonization of information, illustrations, and supporting context	Well-suited
Aesthetic elements	Present
Design or layout	Good
Clarity	Good

As shown in Table 2, assessment of the comics was conducted in eight aspects. All of these aspects received good ratings, except that. An improvement is needed in terms of content related to the concept of sample space (outlined in red). In this case, the experts suggested that the researchers should emphasize random experiments in determining sample spaces, which is pivotal in learning probability. In other words, it was deemed necessary that random experiments be emphasized in developing the content of the comics story to increase its relevance to the student worksheets.

In addition to the comics, assessment was also obtained conducted on the worksheets (Table 3). This assessment of the worksheet was aimed evaluating the worksheet's effectiveness in reinforcing students' understanding of the concept of probability. The experts provided feedback on the clarity, usability, and alignment of the worksheet with the learning objectives, which would be useful for refining the worksheets. This feedback was then carefully analyzed before revisions were made.

Table 3. Summary of ethe results of expert review of student worksheet

No.	Validated Objects	Comment
1.	Content of the student worksheets	
	a. Does the PMRI-based student worksheets contain a mathematics material that aligns with the Independent Curriculum?	Yes
	b. Does the PMRI approach-based student worksheets contain a mathematics material that should be taught to grade 10 students?	Yes
2.	PMRI characteristic reflected in the worksheets	
	Do the student worksheets reflect the following PMRI characteristics?	
	a. Applying real-word problems	Yes
	b. Employing a model as a bridge from informal to formal mathematics	Yes
	c. Valuing linguistic diversity and student participation	Yes
	d. Promoting two-way interaction	Yes
	e. Being merged with other instructional topics	Yes
3.	Media perspectives and significance	
	a. Have the media aspects of the student worksheets been properly included?	Yes
	b. Does the student worksheets effectively reflect the intended educational outcomes?	Yes

Based on Table 3, the content of Prototype 1 was in accordance with the Independent Curriculum, particularly in Phase E. The content about the probability of compound events, with a focus on the sample space sub-topic. The content of the worksheets was in accordance with the five PMRI characteristics. First, it applied real-world problems with culinary tourism used as a context. Second, it employed a model that emphasized informal solutions before using formal methods. In this case, students could create their own models to solve the contextual problems posed to them. Third, it valued linguistic diversity and student participation. The medium used was relevant to the learning objectives. In addition, the questions presented in the student worksheet gave students the opportunity to propose answers according to the results of their respective thinking process in their group, showing some level of respect to the diversity among them. Fourth, it promoted interactivity. The researchers designed the student worksheet in such a way that it would require students to collaborate in groups to work on it. Students engaged in discussion and collaborations to work on sample space problems. Fifth, it supported integration with other learning topics. In this case, sample space, serving as the starting point in learning probability, could be integrated with other topics.

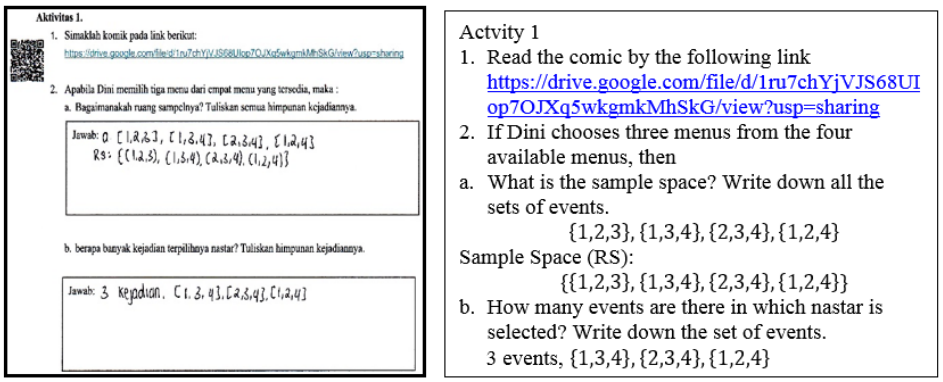
The media aspect and its relevance to the student worksheets were well-rate. In addition, the content of the student worksheets was considered relevant to the learning objectives that had been formulated. However, based on feedback from content experts, it was suggested that the researchers revisit the history of probability theory, considering that the act of selecting food items from a menu

tends to be based on personal preference. This is in line with what Bakker's (2004) suggestion that when instructing on a probability topic, it is advisable for a teacher to first explore the topic's historical background. He argued that understanding the history of the topic would serve as a solid foundation for effectively teaching it. This understanding would allow the teacher to adapt and modify the material according to students' learning needs within the curriculum. In effect, it is expected that this understanding would enhance students' motivation and interest in probability topics.

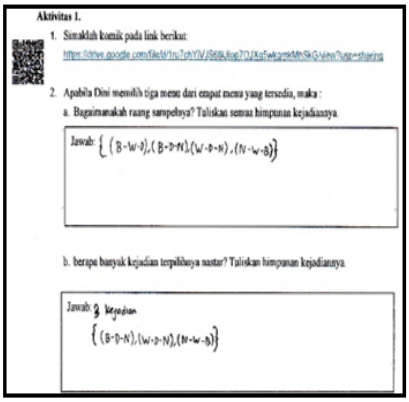
Two-on-one Evaluation

During the two-on-one evaluation, the researchers analyzed how two selected grade 10 students worked on prototype 1. The two students would not be among the study subjects involved in the field test. The evaluation focused on identifying usability issues and on assessing students' engagement with Prototype 1. The feedback from the students provided valuable insights for refining the instructional material to obtain better learning outcomes. The two students were working on worksheets independently. The researchers observed how the process unfolded and recorded some findings. Additionally, notes were gathered based on both observations and interviews. The researchers analyzed these findings to identify students' learning difficulties. The data was then used to refine the worksheet design, ensuring that it would better support students' learning and comprehension, particularly in terms of their reasoning skills.

Based on observations, it was found that the two students provided answers using different models: One used number, while the other used letters (Figure 3). This differential in answer patterns indicated different cognitive approaches to problem-solving that were employed by the two students. Recognizing this difference could help the researcher improve the instructional material contained in the worksheets.



(a)



Actvity 1

1. Read the comic by the following link https://drive.google.com/file/d/1ru7chYjVJS68UIop7OJXq5wkgmkMhSkG/view?usp=sharing
2. If Dini chooses three menus from the four available menus, then
a. What is the sample space? Write down all the sets of events.
$\{(B-W-D),(B-D-N),(N-W-B)\}$
b. How many events are there in which nastar is selected? Write down the set of events.
$\{(B-D-N),(W-D-N),(N-W-B)\}$

(b)

Figure 3. Students' answers

As depicted Figure 3, a link and a barcode were provided that direct students to the educational comics. Following the link and barcode were three key guiding questions to be answered by students after reading the comics, providing a means for discussion and collaboration between students. The comics, which functioned as a microlearning medium, helped students learn about sample space using a culinary tourism context.

Figure 3 presents students' responses related to the concept of sample space. They first engaged with the comics, which served as a microlearning medium, through which the concept of sample space was introduced using the context of the culinary tourism in Prabumulih city. Three provided guiding questions facilitated discussion and collaboration, helping students develop a deeper understanding of the sample space concept. Students A and B recorded all possible outcomes of the experiment and then wrote down the sample space. However, student A used menu numbers, while student B used menu letters. The three problems that were posed, could measure students' conceptual understanding of sample space, as well as their reasoning skills. Students were required to estimate all possibilities that might arise from the experiment of choosing several items of a menu from four available options. Students could estimate combinations of two selected items of the menus from the four available options, allowing them to calculate the probabilities of events in Activity 2, as designed by the researcher.

From the observations, the researchers noticed doubts that arose in the students in solving the problems. These doubts stemmed from their tendency to solve mathematical problems directly using formulas. Additionally, they were rarely exposed to contextual problems that required reasoning, which added to the difficulty that the students faced. Mathematics learning usually is heavily centered on a textbook which contains procedural content. These challenges became a reflection for both the students and the researcher.

Revision

Based on the findings from the expert review and two-on-one evaluation, the researchers revised Prototype 1 to improve its quality, adding the history of probability to it. Traditionally, the birth of the modern concept of probability is attributed to Blaise Pascal and Pierre de Fermat, who used chance to

solve gambling games (Pasuci, 2024). It was from these gambling games that the theory of probability originated. This revision can be seen in Figure 4.

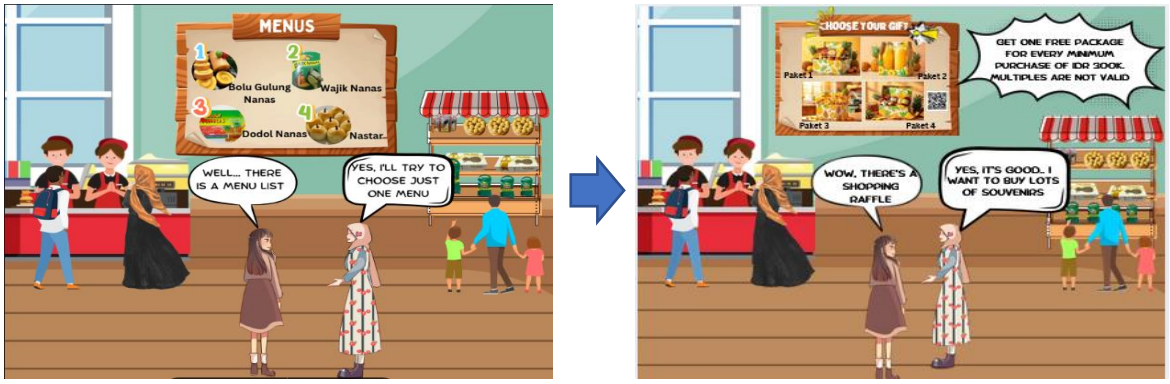


Figure 4. Revision of the comics

Figure 4 illustrates the revised version of some panels of the comics, the names of menu items 1 – 4 were change to Packages 1 – 4. The store informed through a statement that it offered a prize draw that any customers who made amounting to IDR 300,000 could participate in, with no cumulative eligibility. In this study, the researchers adapted the gambling game into the prize draw within the context of culinary tourism in Prabumulih City. The rough draft and revised version of the comics can be viewed at Comics_1 and Comics_2. These changes were made to emphasize the randomness of experiments in learning the concept of sample space. In making these modifications, the researchers realized the importance that a designer understands the history and content of probability theory, as it would help students grasp the concept more effectively. Bakker (2004) stated in his research that studying the history of a topic serves as valuable preparation for teaching it. One of the benefits we gain from this understanding is that it helps students better comprehend the concept and principle that come with the theory. In addition to the comics, revisions were also made to the worksheets.

The modified comics was then integrated into the student worksheets, resulting in Prototype 2 (Table 4). This adjustment ensured that the worksheets were aligned more effectively with the revised comic content, enhancing students' comprehension and engagement. By incorporating elements from the updated comics, the worksheets created a more relatable learning experience. The refinements made to produce Prototype 2 were informed by feedback from previous evaluations, ensuring improved instructional quality and better student understanding.

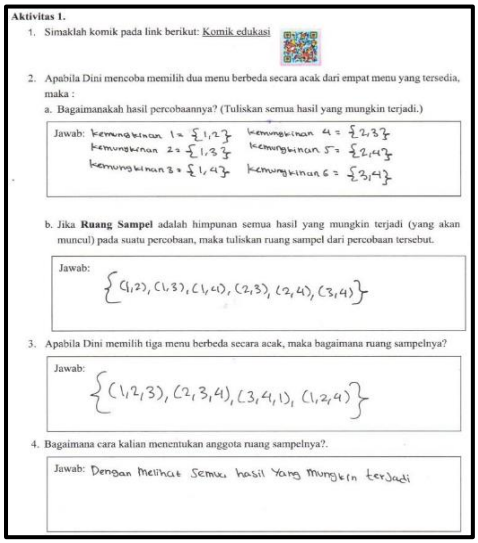
Table 4. Modifications to prototype 1 to make prototype 2

Prototype 1	Prototype 2
A single trial Dini selects three available menu items	Two random experiments 1. Dini randomly selects two different menu items from four available options. 2. Dini randomly selects three menu items from four available options.

As shown in Table 4, the researchers designed two random experiments to guide students in grasping the concept of sample space. These experiments strengthened students' reasoning skills, helping them determine the sample space of the given random experiment. The refinement of Prototype 1 resulted in valid Prototype 2, which was later tested during a small group evaluation.

Small-Group Evaluation

During the small group evaluation, the researchers tested Prototype 2 on groups of four students, except for one group that had three students. Each student focused on completing his or her own worksheets. The researchers observed their progress during the activity and interviewed them afterward. Observations indicated that students successfully completed the worksheets. Additionally, interview results revealed that students found the microlearning comic useful in helping them understand the concept of sample space, and solve the problems presented in the worksheets (Figure 5).


Aktivitas 1.

1. Simaklah komik pada link berikut: Komik edukasi

2. Apabila Dini mencoba memilih dua menu berbeda secara acak dari empat menu yang tersedia, maka :
   a. Bagaimanakah hasil percobaannya? (Tuliskan semua hasil yang mungkin terjadi.)

Jawab: kemungkinan 1 = {1,2} kemungkinan 4 = {2,3}
kemungkinan 2 = {1,3} kemungkinan 5 = {2,4}
kemungkinan 3 = {1,4} kemungkinan 6 = {3,4}

b. Jika **Ruang Sampel** adalah himpunan semua hasil yang mungkin terjadi (yang akan muncul) pada suatu percobaan, maka tuliskan ruang sampel dari percobaan tersebut.

Jawab: {(1,2), (1,3), (1,4), (2,3), (2,4), (3,4)}

3. Apabila Dini memilih tiga menu berbeda secara acak, maka bagaimana ruang sampelnya?

Jawab: {(1,2,3), (2,3,4), (3,4,1), (1,2,4)}

4. Bagaimana cara kalian menentukan anggota ruang sampelnya?.

Jawab: Dengan melihat semua hasil yang mungkin terjadi

English version.
Activity 1.

1. See the following link of comic.
2. If Dini tries to choose two different menus randomly from the four available menus, then:
   a. What were the results of the experiment? (Write down all possible outcomes.)
      Probability 1= {1,2} Probability 4= {2,3}
      Probability 2= {1,3} Probability 5= {2,4}
      Probability 3= {1,4} Probability 6= {3,4}
   b. If the Sample Space is the set of all possible outcomes (that will occur) in an experiment, then write the sample space of the experiment. {(1,2), (1,3), (1,4), (2,3), (2,4), (3,4)}
3. If Dini chooses three different menus at random, what is the sample space? {(1,2,3), (2,3,4), (3,4,1), (1,2,4)}
4. How do you determine the members of the sample space? by looking at all possible outcomes

Figure 5. Student answers from a small-group discussion

Figure 5 presents a student group's answers, showing successful problem-solving. The students accurately determined the sample space of the random experiment. This showed that they had strong reasoning skills. From these answers, it could be inferred that the students had understood the concept of sample space. To determine the members of a sample space, students' reasoning ability is essential. The students were able to provide correct answers to the sample space problems, where the random experiment involved a prize draw with a spinning wheel and the students were required to predict all possible outcomes.

The contextual problems that were presented, revealed the students' thinking flexibility by which various methods were generated. This is in line with Arifin et al. (2021) take that flexibility of thinking is reflected in the possibility of different ideas and the ability to change methods or approaches to problem-solving quickly. The students being able to produce the right solutions showed that they were able to use their reasoning skills to solve the problems at hand.

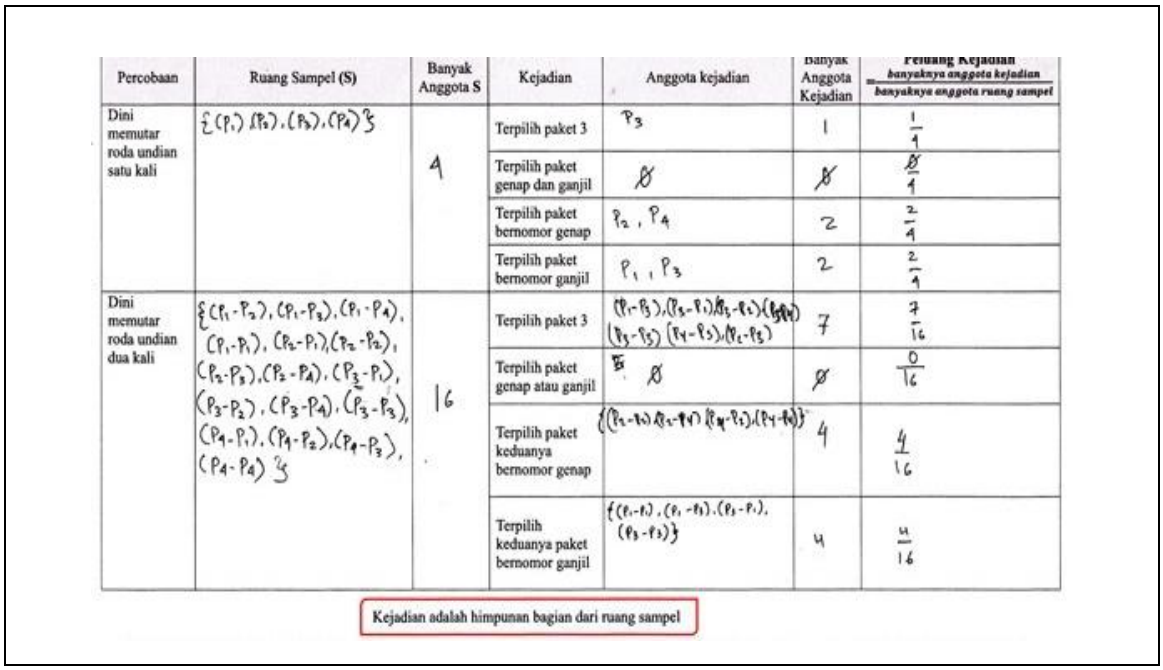
The comics increased the student's motivation to learn sample space, as can be seen from their answers in the student worksheets. These findings also showed that probability learning was effective in enhancing students' reasoning skills. Students had shown a good understanding of the concept of probability. Sharna et al. (2021) said that the appeal of comics lies in its ability to arouse students' enthusiasm for learning due to the alignment of content that is relevant to their lives. This enthusiasm is key to understanding text.

Observations and analysis of students' answers revealed that Prototype 2 was effective and efficient for teaching probability, so it could be used in the field test. As stated (Tessmer, 1993), small-group evaluations focus on student performance data to confirm previous revisions and provides more accurate measures of learner performance.

Field Test Evaluation

In the field test stage, the learning process was conducted by a model teacher, involving 34 grade 10 students, who were then divided into 11 groups. The model teacher delivered the probability material to students. Throughout the evaluation, the researchers acted as observers, assessing how effectively both the teacher and students engaged with the instructional material provided through the student worksheet. Instruction was carried out in the best possible way, although some improvements might be necessary.

Based on the researchers' s observations, students appeared enthusiastic during the learning process. A number of students acted out comics characters in front of the class, watched by the rest of the students. The students 'answers in the student worksheet also demonstrated good performance, with the students successfully determining the members of a sample space and the probability of an event, occurring in Figure 6.



Percobaan	Ruang Sampel (S)	Banyak Anggota S	Kejadian	Anggota kejadian	Banyak Anggota Kejadian	Peluang Kejadian $= \frac{\text{banyaknya anggota kejadian}}{\text{banyaknya anggota ruang sampel}}$
Dini memutar roda undian satu kali	{(P1), (P2), (P3), (P4)}	4	Terpilih paket 3	P3	1	1/4
			Terpilih paket genap dan ganjil	∅	∅	∅/4
			Terpilih paket bernomor genap	P2 , P4	2	2/4
			Terpilih paket bernomor ganjil	P1 , P3	2	2/4
Dini memutar roda undian dua kali	{(P1-P2), (P1-P3), (P1-P4), (P1-P1), (P2-P1), (P2-P2), (P2-P3), (P2-P4), (P3-P1), (P3-P2), (P3-P4), (P3-P3), (P4-P1), (P4-P2), (P4-P3), (P4-P4)}	16	Terpilih paket 3	(P1-P3), (P2-P3), (P3-P1), (P3-P2), (P3-P3), (P4-P3), (P3-P4)	7	7/16
			Terpilih paket genap atau ganjil	∅	∅	0/16
			Terpilih keduanya bernomor genap	{(P2-P2), (P2-P4), (P4-P2), (P4-P4)}	4	4/16
			Terpilih keduanya paket bernomor ganjil	{(P1-P1), (P1-P3), (P3-P1), (P3-P3)}	4	4/16

Kejadian adalah himpunan bagian dari ruang sampel

English version:

Activity 2. Using the obtained experimental results, fill in the following table.

Experiment	Sample Space (S) elements	Total number of possible outcomes	Event	Event elements	Number of ways the event occur	$= \frac{Probability\ of\ an\ Event\ number\ of\ ways\ the\ event\ can\ occur}{Total\ number\ of\ possible\ outcomes}$
Dini spun the lottery wheel once			Package 3 has been chosen			
			The even and odd packages have been chosen			
			The even-numbered package has been chosen			
			The odd-numbered package has been chosen			
Dini spun the lottery wheel twice			Package 3 has been chosen			
			The even-numbered package was chosen in the first round, and the odd-numbered package in the second round			
			Both of the even-numbered packages were chosen			
			Both of the odd-numbered packages were chosen			

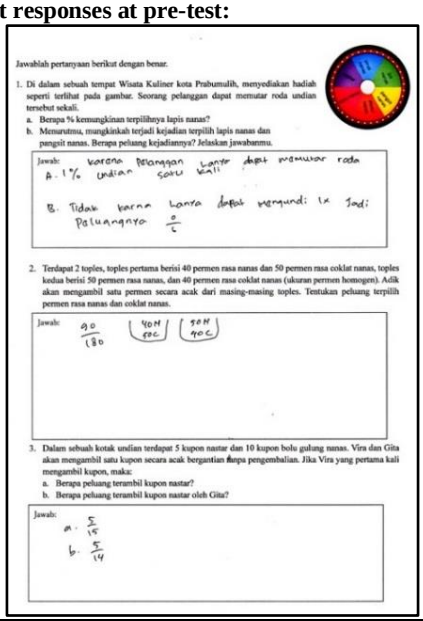
An event is a subset of the sample space

Figure 6. Student's answers in the worksheets

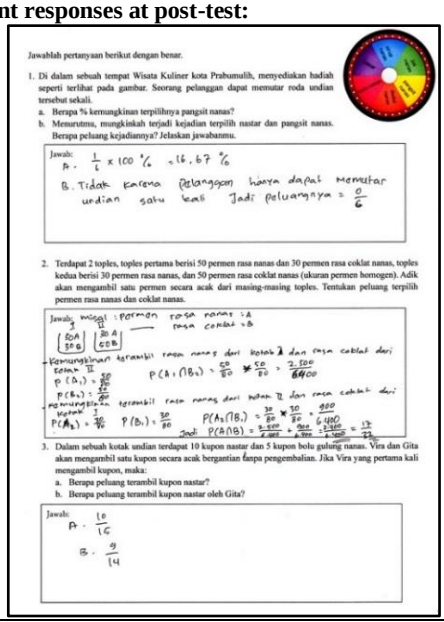
Figure 6 shows the response of one student in Activity 2 of the worksheets. The student was asked to list all the elements of a sample space and the possible events from a random experiment of spinning a lottery wheel. The answer provided demonstrated the student's understanding of the sample space concept and ability to identify possible events. These answers also showed that the student had been able to use their reasoning skills and understand the concept of event probability.

Students' achievement post-test also showed an increase compared to pre-test results. The researchers found that the performance of students' answer was significantly different between the pre-test and post-test, can be seen in Figure 7. This improvement suggests that the instructional material and teaching strategies implemented during the study contributed to students' enhanced understanding of the subject. The difference in students' responses indicated a positive impact on their reasoning abilities.

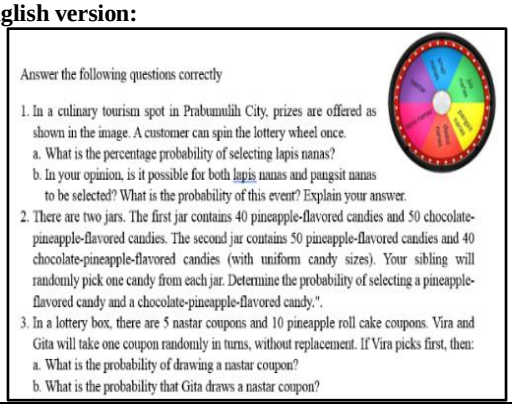
Student responses at pre-test:



Student responses at post-test:



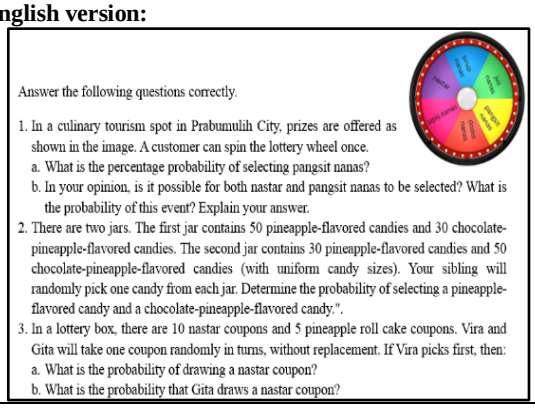
English version:



Answer the following questions correctly

1. In a culinary tourism spot in Prabumulih City, prizes are offered as shown in the image. A customer can spin the lottery wheel once.
   a. What is the percentage probability of selecting lapis nanas?
   b. In your opinion, is it possible for both lapis nanas and pangsit nanas to be selected? What is the probability of this event? Explain your answer.
2. There are two jars. The first jar contains 40 pineapple-flavored candies and 50 chocolate-pineapple-flavored candies. The second jar contains 50 pineapple-flavored candies and 40 chocolate-pineapple-flavored candies (with uniform candy sizes). Your sibling will randomly pick one candy from each jar. Determine the probability of selecting a pineapple-flavored candy and a chocolate-pineapple-flavored candy.".
3. In a lottery box, there are 5 nastar coupons and 10 pineapple roll cake coupons. Vira and Gita will take one coupon randomly in turns, without replacement. If Vira picks first, then:
   a. What is the probability of drawing a nastar coupon?
   b. What is the probability that Gita draws a nastar coupon?

English version:



Answer the following questions correctly.

1. In a culinary tourism spot in Prabumulih City, prizes are offered as shown in the image. A customer can spin the lottery wheel once.
   a. What is the percentage probability of selecting pangsit nanas?
   b. In your opinion, is it possible for both nastar and pangsit nanas to be selected? What is the probability of this event? Explain your answer.
2. There are two jars. The first jar contains 50 pineapple-flavored candies and 30 chocolate-pineapple-flavored candies. The second jar contains 30 pineapple-flavored candies and 50 chocolate-pineapple-flavored candies (with uniform candy sizes). Your sibling will randomly pick one candy from each jar. Determine the probability of selecting a pineapple-flavored candy and a chocolate-pineapple-flavored candy.".
3. In a lottery box, there are 10 nastar coupons and 5 pineapple roll cake coupons. Vira and Gita will take one coupon randomly in turns, without replacement. If Vira picks first, then:
   a. What is the probability of drawing a nastar coupon?
   b. What is the probability that Gita draws a nastar coupon?

Figure 7. Student responses on the pretest and the posttest questions

As shown in Figure 7, the posttest questions were slightly similar to the pretest questions, except that the researchers modified the numerical values. The student's answer on the posttest were significantly better than the answers on the pre-test, especially to the second question. The student was able to determine the probability of choosing candies from each jar in an experiment and make a prediction of the likelihood of retrieving pineapple-flavored candies from jar 1 and retrieving chocolate-flavored candies from jar 2, or vice versa. Analysis of students' answers revealed that there were students who gave only one possible answer. This was because the students had different ways of imagining the problem.

The overall test results can be seen in Figure 6. The field test was conducted on 34 participants. The students involved were those who did not participate in the two-on-one and small-group evaluations. The test included three questions (Figure 7). Those questions were designed to evaluate students' understanding of probability concepts and their ability to apply logical reasoning in problem-solving situations. The results provided insights into how well students grasped key ideas and highlighted areas needing further instructional support.

Table 6. Result of the test

Score	Pre-test (%)	Post-test (%)	Category
86 – 100	0	6	Excellent
71 – 85,99	15	35	Good
56 – 70,99	6	35	Satisfactory
40 – 55,99	21	24	Poor
< 40	59	0	Very poor

From Table 6, the students made an improvement from pre-test to post-test. At pre-test, no students fell to excellent category, but at post-test, 6% of students belonged in this category. Likewise, 59% of students fell to the very poor category at pretest, whereas at post-test, no students belonged in this category. These findings indicates that the worksheet developed by the researchers were effective and efficient in helping students in learn probability and enhance their reasoning skills. The substantial shift in performance distribution reflects the positive influence of integrating microlearning comics into instructional materials.

The post-test questions, though structurally similar to the pre-test, challenged students with modified numerical values to assess their conceptual transfer. Students showed noticeable improvement, especially in interpreting compound probability scenarios involving flavored candies. Variation in students' responses revealed flexible thinking patterns, highlighting diverse cognitive strategies. These results affirm the value of differentiated instructional tools such as microlearning comic integrated worksheets in developing probabilistic reasoning and fostering inclusive learning experience.

The improvement in students' learning outcomes from the pre-test to the post-test indicates the effectiveness of the student worksheets integrated with microlearning comics in enhancing students' understanding of probability concepts. This aligns with Aldosemani (2019) findings, which highlight that microlearning strategies allow learners to access content in concise, manageable segments, promoting retention and flexible learning. Furthermore, the visual and narrative elements of comics serve as effective cognitive scaffolds that support comprehension of abstract mathematical concepts. As Lam et al. (2023) assert, comics in mathematics instruction can improve student engagement and foster future-ready learning competencies, particularly when designed to align with curricular goals.

Moreover, the students' ability to transfer conceptual understanding to novel contexts, such as solving compound probability problems involving flavoured candies, demonstrates growth in probabilistic reasoning. This supports the perspective of Álvarez et al. (2024), who emphasize the importance of fostering probabilistic literacy to help students interpret uncertain events in real-world situations. The differentiated nature of the instructional materials accommodated diverse learning preferences, contributing to a more inclusive and equitable learning environment (McNeill & Fitch, 2023). In line with the principles of *Pendidikan Matematika Realistik Indonesia*, which emphasize contextual learning and mathematization (Zulkardi, 2002; Zulkardi & Putri, 2020), the use of microlearning comics allowed students to meaningfully engage with probability through realistic scenarios, thereby strengthening both conceptual understanding and reasoning skills.

CONCLUSION

In this study, the researchers developed the student worksheets on probability for grade 10, integrated with microlearning comics using the context of culinary tourism in Prabumulih City. The products demonstrated the following characteristics. First, the construct was designed in accordance with the PMRI approach. The material began with the presentation of the context of culinary tourism in Prabumulih City, followed by several questions related to the given context. Second, the answers to the problems were presented as student contributions. This helped students understand the concept of sample space while simultaneously strengthening their reasoning skills. Third, as a microlearning medium, the comics presented a concise material on the topic of sample space. Fourth, the microlearning comics integrated in the worksheets was easy to use, effective, and efficient, making it a valuable tool for enhancing students' reasoning skills. Based on the study results, the microlearning

comics could help with students' learning and thus, integrating it into the student worksheets could further develop students' reasoning skills. Students were able to determine the sample space of a random experiment based on the contextual problem presented. A limitation of this research is that the study was conducted at only one school. It is hoped that future research will include multiple schools to provide a clearer assessment of the effectiveness and efficiency of the instructional worksheets. This initiative aligns with Sustainable Development Goal 4, which advocates for inclusive and equitable quality education and promotes lifelong learning opportunities for all. By integrating relevant contexts into learning materials, the worksheets contribute to enhancing educational equity and engagement, while simultaneously advancing the quality of mathematics instruction.

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DECLARATIONS

Author Contribution : NK: Conceptualization, Writing - Original Draft, Editing and Visualization; YH: Writing - Review & Editing, Methodology, Validation, and Supervision RIIP: Writing-Review & Editing, Formal Analysis, Validation, and Supervision;
CH: Writing-Review & Editing, Validation and Supervision;)

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REFERENCES

Aldosemani, T. I. (2019). Microlearning for macro-outcomes: students' perceptions of telegram as a microlearning tool. In *Lecture Notes in Educational Technology*. Springer: Singapore. https://doi.org/10.1007/978-981-13-7361-9_13

Álvarez, R., Carmen, A., & María, B. (2024). *Probabilistic literacy and reasoning of prospective secondary school teachers when interpreting media news*. *ZDM – Mathematics Education* 56:1045–1058. https://doi.org/10.1007/s11858-024-01586-8

Arican, M., & Kuzu, O. (2019). Diagnosing Preservice Teachers _ Understanding of Statistics and Probability : Developing a Test for Cognitive Assessment. *International Journal of Science and Mathematics Education*. https://doi.org/10.1007/s10763-019-09985-0

Arifin, S., Zulkardi, Putri, R.I.I., & Hartono, Y. (2021). On creativity through mathematization in solving non-routine problems. *Journal on Mathematics Education,* 12(2), 313-330. http://doi.org/10.22342/jme.12.2.13885.313-330

Armiati, Fauzan, A., Harisman, Y., & Sya'Bani, F. (2022). Local instructional theory of probability topics based on realistic mathematics education for eight-grade students. *Journal on Mathematics Education*, *13*(4), 703–722. https://doi.org/10.22342/jme.v13i4.pp703-722

Astuti, D., Anggraeni, L., & Setyawan, F. (2020). Mathematical probability: Student's misconception in higher education. *Journal of Physics: Conference Series*, *1613*(1). https://doi.org/10.1088/1742-6596/1613/1/012009

BSKAP. (2024). *Decree of the Head of the Education Standards, Curriculum, and Assessment Agency of the Ministry of Education, Culture, Research, and Technology Number 032/H/KR/2024 concerning Learning Achievements in Early Childhood, Elementary Education Level, and Secondary Education Level in the Independent Curriculum*. In Kemendikbudristek BSKAP RI.

Batanero, C., & Álvarez, R. (2024). Teaching and learning of probability. *ZDM – Mathematics Education*, *56*(1), 5–17. https://doi.org/10.1007/s11858-023-01511-5

Bakker, A. (2004). *Design research in statistics education on symbolizing and computer tools*. [Doctoral thesis 1 (Research UU / Graduation UU), Utrecht University]. Freudenthal Institute. https://dspace.library.uu.nl/handle/1874/893

Dolasinski, M. J., & Reynolds, J. (2020). Microlearning: A New Learning Model. *Journal of Hospitality and Tourism Research*, *44*(3), 551–561. https://doi.org/10.1177/1096348020901579

Greenwood, D., Wooley, S., Vaughan, J., Frank, F., Goodman,J., & Robertson, D. (2011). Essential Mathematics for The Australian Curriculum Year 9. Australia: Cambridge University Press.

Groove, M. (2018). Math in Focus Mathematics Extention 1. Australia: Copyright Agency Limited.

Hiltrimartin, C., Hartono, Y., & Indaryanti, I. (2022). Development of Student Activities in Algebra based on Problem Solving in Middle School. *Proceedings of the 2nd National Conference on Mathematics Education 2021 (NaCoME 2021)*, *656*(NaCoME 2021), 47–55. https://doi.org/10.2991/assehr.k.220403.008

Lam, T. O. H. T., Pien, C. L., Hean, L. I. M. L., & Ming, L. I. M. K. (2023). *Comicss for Mathematics Instruction for Future-Ready Learners*. *4*(2), 165–178. https://ame.org.sg/2023/09/06/tme2023-vol-4-no-2-pp-165-178

Malalina, Indra Putri, R. I., Zulkardi, & Hartono, Y. (2024). Developing mathematics teaching materials using maritime context for higher-order thinking in junior high school. *Journal on Mathematics Education*, *15*(1), 173–190. http://doi.org/10.22342/jme.v15i1.pp173-190

McNeill, L., & Fitch, D. (2023). Microlearning through the Lens of Gagne's Nine Events of Instruction: A Qualitative Study. *TechTrends*, *67*(3), 521–533. https://doi.org/10.1007/s11528-022-00805-x

OECD (2023), *PISA 2022 Results (Volume I): The State of Learning and Equity in Education*, PISA, OECD Publishing, Paris. https://doi.org/10.1787/53f23881-en

Pascucci, A. (2024). *Probability Theory I*. Italy: Springer. https://doi.org/10.1007/978-3-031-63190-0.

Tessmer M. (1993). *Planning and Conducting Formative Evaluation*. In London, Philadelphia:Kogan Page. https://doi.org/10.4324/9780203061978

Sari, D. L., Fitriani, D. A., Khaeriyah, D. Z., Hartono, & Nursyahidah, F. (2022). *Hypothetical learning trajectory on probability material:* The context of the traditional dragon snake toy. *11*(2), 203–214. http://journal.institutpendidikan.ac.id/index.php/mosharafa

Sharma, S., Sharma, S., Doyle, P., Marcelo, L., & Kumar, D. (2021). Teaching and learning probability using games: A systematic review of research from 2010–2020. Waikato Journal of Education, 26(2), 51–64. https://doi.org/10.15663/wje.v26i2.881

Waheed, H., Hassan, S., Nawaz, R., Aljohani, N. R., & Chen, G. (2023). Early prediction of learners at risk in self-paced education : A neural network approach. *Expert Systems With Applications*, *213*(PA), 118868. https://doi.org/10.1016/j.eswa.2022.118868

Wijaya, A., Elmaini, & Doorman, M. (2021). A learning trajectory for probability: A case of game-based learning. *Journal on Mathematics Education*, *12*(1), 1–16. https://doi.org/10.22342/JME.12.1.12836.1-16

Wijaya, T. T., Hidayat, W., Hermita, N., Alim, J. A., & Talib, C. A. (2024). Exploring contributing factors to PISA 2022 mathematics achievement: Insights from Indonesian teachers. *Infinity, 13(1)*, 139-156. https://doi.org/10.22460/infinity.v13i1.p139-156

Zulkardi. (2002). Developing a learning environment on realistic mathematics education for Indonesian student teachers. PrintPartners Ipskamp. https://ris.utwente.nl/ws/portalfiles/portal/6073266/thesis_Zulkardi.pdf

Zulkardi, Putri, R. I. indra, & Wijaya, A. (2020). *Two decades of realistic mathematics education in Indonesia*. https://doi.org/10.1007/978-3-030-20223-1_18

Zulkardi, Z., & Putri, R. I. I. (2020). Supporting Mathematics Teachers to Develop Jumping Task Using PISA Framework (JUMPISA). *Jurnal Pendidikan Matematika*, *14*(2), 199–210. https://doi.org/10.22342/jpm.14.2.12115.199-210