© IJARW | ISSN (O) - 2582-1008
May 2026 | Vol. 7 Issue. 11
www.ijarw.com

CONCEPTUAL UNDERSTANDING on PROBABILITY and STATISTICS among SENIOR HIGH SCHOOL LEARNERS using META-COMPREHENSION STRATEGY

Allain Mae J. Abao

College of Education, Bukidnon State University, Malaybalay City 8700, Bukidnon, Philippines

ABSTRACT

This study investigated the effects of using the meta-comprehension strategy in enhancing the conceptual understanding of grade 11 learners on probability distribution. It was conducted at one of the public high schools in Misamis Oriental division during the school year 2019-2020. A quasi-experimental pretest-posttest group design was used with two intact groups. The participants of the study were 60 grade 11 learners, with the first group taught with lessons on probability distribution using the K-to-12 strategy while the second group taught with the same lessons on probability distribution using the meta-comprehension strategy, survey, question, read, question, compute, question (SQRQCQ) strategy. This study utilized a 30-item researcher-made conceptual understanding test as research instrument. The data gathered were tested using mean, standard deviation, frequency, percentage, and one-way analysis of covariance (ANCOVA). Results indicated that students exposed to the SQRQCQ meta-comprehension strategy achieved a level of conceptual understanding similar to those taught through the K to 12 suggested strategies, suggesting that both instructional approaches were equally effective across most competencies. This implies that the K to 12 suggested strategies were effective in developing learners' foundational understanding of basic probability distribution concepts, while the SQRQCQ meta-comprehension strategy was more beneficial in enhancing higher-order thinking skills such as reasoning, analysis, and problem-solving. However, the SQRQCQ strategy was found to be significantly more effective in enhancing learners' understanding of variance in a discrete probability distribution. The learners are encouraged to continue using the SQRQCQ strategy as a structure approach to studying probability distribution, focusing on developing metacognitive skills and deeper understanding.

Keywords: conceptual understanding, meta-comprehension strategy, probability distribution, discrete probability distribution, education, mathematics, metacognition

1. INTRODUCTION

The concept of probability distribution is a fundamental component of statistics that explains the likelihood of outcomes in experiments and real-life situations. In mathematics education, probability helps students develop critical thinking, analytical reasoning, and problem-solving skills necessary for interpreting uncertainty and making informed judgments. According to Kishore (2023), learning probability enables students to appreciate the role of chance and uncertainty in everyday life. Despite its importance, probability distributions remain among the most challenging mathematical topics for learners due to their abstract concepts and computational demands.

One persistent problem in mathematics education is the difficulty students experience in achieving conceptual understanding of probability distribution. Traditional instructional approaches often emphasize memorization, formula application, and repetitive drills rather than meaningful understanding and interpretation of concepts. As a result, many students struggle to apply probability concepts in authentic and real-world contexts. Engelbrecht et al. (2020) argued that conceptual understanding involves recognizing the relationships among mathematical ideas rather than merely recalling procedures. Furthermore, students who lack conceptual understanding struggle with probabilistic reasoning, data interpretation, and critical analysis. These concerns highlight the need for instructional approaches that actively engage learners and develop deeper cognitive processing in mathematics classrooms.

Several studies and related literature underscore the importance of metacognition and active learning in improving mathematics achievement and comprehension. Metacognition refers to an individual's awareness and regulation of cognitive processes during learning activities (Desoete & De Craene, 2019; Jin & Kim, 2018). According to Stanton (2022), connecting prior knowledge with newly learned concepts significantly enhances conceptual understanding and retention in mathematics. Moreover, active learning approaches such as self-evaluation, reflective questioning, and video feedback contribute to learners' metacognitive development and self-awareness (Yeh et al., 2019). One metacognitive approach is the SQRQCQ strategy, which originated with Robinson's (1941) SQ3R and was later adapted by Fay (1965) for mathematical problem-solving. This strategy encourages learners to survey, question, read, question again, compute, and question their solutions, thereby promoting reflective and strategic thinking during problem-solving activities. Although previous studies support the effectiveness of metacognitive strategies in mathematics learning, few have specifically examined the effectiveness of the SQRQCQ meta-comprehension strategy in teaching probability distributions to senior high school learners. This gap in the literature necessitates further investigation.

In the Philippine context, mathematics instruction in many senior high school classrooms continues to rely heavily on lecture-based teaching and drill-oriented exercises. While these methods may improve procedural fluency, they often fail to cultivate deeper conceptual understanding and critical thinking skills among learners. This instructional concern is evident among senior high school students at a public high school in Misamis Oriental, where learners struggle to understand probability distribution concepts. Given the K–12 curriculum's goals to develop higher-order thinking and problem-solving competencies, there is a growing need for innovative instructional strategies that encourage active participation, self-monitoring, and meaningful engagement with mathematical ideas.

The integration of metacognitive approaches such as the SQRQCQ strategy may therefore provide opportunities to improve students' understanding and retention of mathematical concepts. Given these concerns, this study aimed to determine the effectiveness of the SQRQCQ meta-comprehension strategy in enhancing the conceptual understanding of probability distribution among senior high school learners. The findings of this study are expected to contribute significantly to mathematics education and instructional practice.

2. METHODS

2.1 Research Design

The study utilized a quasi-experimental pretest-posttest group design to investigate the effects of the *survey, question, read, question, compute, question* (SQRQCQ) strategy on learners' conceptual understanding of probability distributions. This design used two intact classes: one class used the meta-comprehension strategy for lessons on probability distributions. In contrast, the other class used the same lessons on probability distribution using the suggested K to 12 strategies. The researcher conducted pretests and posttests for both groups. Furthermore, the test results were analyzed using appropriate statistical tools.

2.1 Research Locale

The study was conducted at one of the public schools in Misamis Oriental during the 2019-2020 school year. The school was founded in 1993, and it is now 33 years old.

The principal heads the school and has 15 teaching personnel. It serves 405 students and has 11 buildings. Grade 7 has three sections; grades 8, 9, and 10 have two sections each; and grades 11 and 12 have four sections each. The school is one of the senior high schools in Alubijid West District, division of Misamis Oriental. It is a small school in terms of population, but the area is large enough to build another building.

Functional organizations and clubs are organized within the school, with members regularly participating in school, division, regional, and national competitions. It also has one science and computer laboratory with internet access, which is readily available for teachers and students.

Students and teachers regularly attended competitions at the division, regional, and national levels, particularly press conferences, MTAP, and palarong pambansa. In general, the school actively engages in various math-related activities, both during regular events and classes and outside them. It means the school actively promotes and participates in math-focused events, competitions, and programs, both on its premises and beyond. The school recognizes the importance of providing students with opportunities to enhance their mathematical skills and knowledge through hands-on experiences and real-world applications. By actively involving students in math activities, the school fosters a supportive and enriching learning environment that extends beyond traditional classroom settings.

3. RESULTS AND DISCUSSIONS

Table 1

Level of Conceptual Understanding of Probability Distribution

Level of Conceptual Understanding	Scoring Range	Control Pre (f/%)	Control Post (f/%)	Experimental Pre (f/%)	Experimental Post (f/%
Complete Understanding (CU)	61-90	0 (0%)	1 (3.33%)	0 (0%)	3 (10%
Partially Complete Understanding (PCU)	31-60	1 (3.33%)	10 (33.33%)	0 (0%)	5 (16.67
Incomplete Understanding (IU)	0-30	29 (96.67%)	19 (63.33%)	30 (100%)	22 (73.33
Mean		16.02	27.18	15.00	26.1
SD		5.48	16.84	0.00	19.9
QD		*IU*	*IU*	*IU*	*IU*

Table 1 presents the overall level of conceptual understanding of learners' probability distributions before and after instruction in both the control and experimental groups. The results indicate that the majority of learners in both groups demonstrated incomplete understanding (IU) during the pretest and remained within the same qualitative description in the posttest. However, improvements in scores and distribution of responses were observed. In the pretest, the control group recorded 29 learners (96.67%) with incomplete understanding, while only 1 learner (3.33%) reached the partially complete understanding level. Similarly, the experimental group showed 30 learners (100%) under *incomplete understanding*, indicating that learners initially had very limited conceptual knowledge of probability distribution.

Table 2

Level of Conceptual Understanding on Exploring Random Variables

Level of Conceptual Understanding	Scoring Range	Control Pre (f/%)	Control Post (f/%)	Experimental Pre (f/%)	Experimental Post (f/%)
Complete Understanding (CU)	19-27	0 (0%)	1 (3.33%)	0 (0%)	2 (6.67%)
Partially Complete Understanding (PCU)	10-18	3 (10%)	7 (23.33%)	1 (3.33%)	5 (16.67%)
Incomplete Understanding (IU)	0-9	27 (90%)	22 (73.33%)	29 (96.67%)	23 (76.67%)
Mean		5.45	7.59	4.82	7.32
SD		2.85	5.03	1.71	5.47
QD		*IU*	*IU*	*IU*	*IU*

Table 2 indicates that both groups initially showed widespread *incomplete understanding (IU)* of random variables, with 90% of the control group and 96.67% of the experimental group falling into this category, suggesting weak foundational knowledge and flawed reasoning. After the intervention, both groups improved, as reflected in higher mean scores and an increased number of students moving to *partial* or *complete understanding*, eight in the control group and seven in the experimental group. Despite these gains, both groups remained at the IU level in the overall qualitative description, indicating the need for further instructional support to achieve full conceptual proficiency.

Analysis of students' responses during the pretest revealed several recurring misconceptions. A common error involved misidentifying possible values of the random variable. Some students omitted valid outcomes or included impossible ones. For example, in a two-coin experiment, responses such as "X = 1, 2, 3" were given, showing a misunderstanding of the sample space. It indicates difficulty in enumerating outcomes and connecting them to the values of the random variable.

Table 3

Level of Conceptual Understanding on Constructing Probability Distributions

Level of Conceptual Understanding	Scoring Range	Control Pre (f/%)	Control Post (f/%)	Experimental Pre (f/%)	Experimental Post (f/%)
Complete Understanding (CU)	13-18	0 (0%)	0 (0%)	0 (0%)	1 (3.33%)
Partially Complete Understanding (PCU)	7-12	3 (10%)	13 (43.33%)	3 (10%)	8 (26.67%)
Incomplete Understanding (IU)	0-6	27 (90%)	17 (56.67%)	27 (90%)	21 (70%)
Mean		3.65	5.82	3.65	5.15
SD		1.95	3.22	1.95	3.44
QD		*IU*	*IU*	*IU*	*IU*

© IJARW | ISSN (O) - 2582-1008
May 2026 | Vol. 7 Issue. 11
www.ijarw.com

Table 3 shows that both groups began with identical pretest results: 90% (27 students) exhibited *incomplete understanding* (IU), while 10% (3 students) had *partially complete understanding* (PCU). Both groups had a mean score of 3.65 (SD = 1.95), which was qualitatively described as IU.

Posttest results revealed marginal improvements in both groups. In the control group, 43.33% (13 students) moved to *partially complete understanding* (PCU), raising the mean score to 5.82 with a standard deviation of 3.22. In the experimental group, one student achieved *complete understanding* (CU), while 26.67% (8 students) reached PCU, resulting in a mean score of 5.15 and a standard deviation of 3.44.

Despite these gains, both groups' post-test mean scores remained within the *incomplete understanding* range, indicating that most students have yet to master constructing probability distributions. The pretest data show that both groups started with nearly identical levels of *incomplete understanding* (IU). After the intervention, both groups improved, with the control group showing a greater increase in *partially complete understanding* (PCU), rising from 10% to 43.33%. In comparison, the experimental group recorded a smaller increase to 26.67%, although one student reached *complete understanding*. Mean scores also improved from 3.65 to 5.82 in the control group and from 3.65 to 5.15 in the experimental group; however, both groups remained within the IU range, indicating that, while progress occurred, constructing probability distributions continues to be a major difficulty for most learners, with the control group showing slightly stronger overall gains.

The persistence of *incomplete understanding* among students suggests the presence of several misconceptions in constructing probability distributions. Many students failed to recognize that the sum of all probabilities in a distribution must equal 1, leading to incomplete or incorrect probability tables. This misconception may stem from insufficient emphasis on the fundamental properties of probability and limited opportunities to verify their answers. Additionally, students showed confusion between the values of the random variable and their corresponding probabilities, indicating a lack of clarity in distinguishing outcomes from their likelihoods. It may be attributed to a lack of foundational knowledge of random variables.

Table 4

Level of Conceptual Understanding on Computing the Mean of a Discrete Probability Distribution

Level of Conceptual Understanding	**Scoring Range**	**Control** Pre (f/%)	**Control** Post (f/%)	**Experimental** Pre (f/%)	**Experimental** Post (f/%)
Complete Understanding (CU)	13-18	0 (0%)	1 (3.33%)	0 (0%)	4 (13.33%)
Partially Complete Understanding (PCU)	7-12	0 (0%)	7 (23.33%)	0 (0%)	7 (23.33%)
Incomplete Understanding (IU)	0-6	30 (100%)	22 (73.33%)	30 (100%)	19 (63.33%)
Mean		3.00	4.93	3.00	6.18
SD		0.00	3.36	0.00	4.54
QD		*IU*	*IU*	*IU*	*IU*

Table 4 shows that 100% of students in both groups initially exhibited *incomplete understanding* (IU), indicating no prior knowledge of computing the mean of discrete probability distributions. Post-intervention results demonstrated notable improvement in both groups. In the control group, *incomplete understanding* (IU) decreased to 73.33%, while 23.33% of students advanced to *partially complete understanding* (PCU) and 3.33% reached *complete understanding* (CU). In the experimental group, IU further declined to 63.33%, with 23.33% attaining PCU and 13.33% achieving CU, indicating greater overall gains than in the control group. Ultimately, both groups benefited from instruction, but the experimental group attained a higher level of conceptual mastery.

Post-instruction results indicate that both groups improved, although the experimental group demonstrated greater gains. It is reflected in the higher number of students reaching Complete Understanding and a higher post-test mean score of 6.18 compared to 4.93 in the control group, suggesting that the instructional approach used in the experimental group was more effective.

Table 5

Level of Conceptual Understanding on Computing the Variance of a Discrete Probability Distribution

Level of Conceptual Understanding	Scoring Range	Control Pre (f/%)	Control Post (f/%)	Experimental Pre (f/%)	Experimental Post (f/%)
Complete Understanding (CU)	9-12	0 (0%)	0 (0%)	0 (0%)	6 (20%)
Partially Complete Understanding (PCU)	5-8	1 (3.33%)	4 (13.33%)	0 (0%)	3 (10%)
Incomplete Understanding (IU)	0-4	29 (96.67%)	26 (86.67%)	30 (100%)	21 (70%)
Mean		2.15	2.60	2.00	4.15
SD		0.81	1.53	0.00	3.44
QD		*IU*	*IU*	*IU*	*IU*

Table 5 shows that both groups began with nearly zero knowledge of computing variance. In the pretest, 96.67% of the control group and 100% of the experimental group exhibited *incomplete understanding* (IU). After the intervention, the control group showed minimal progress, with *incomplete understanding* (IU) decreasing only slightly to 86.67%. In contrast, the experimental group demonstrated significantly higher gains, with 20% of students achieving *complete understanding* (CU) and IU dropping to 70%. Ultimately, while both groups improved, the experimental group showed a much stronger capacity to move students toward total conceptual mastery of variance.

The findings show that while both groups improved, the experimental group achieved a more significant boost in understanding, with a higher post-test mean (4.15 vs. 2.60) and several students achieving *complete understanding*, whereas the control group produced none. Despite this progress, both groups remained at the *incomplete understanding* (IU) level overall due to persistent challenges, including confusion between variance and standard deviation, where students incorrectly applied square roots mid-calculation, and mapping errors, where they struggled to link outcomes with their corresponding probabilities in tables correctly. To put it simply, while the new teaching method worked better, most students still have not fully mastered the "why" behind variance and need more focused help to get it right.

Table 6

Level of Conceptual Understanding on Solving Problems Involving Mean and Variance

Level of Conceptual Understanding	Scoring Range	Control Pre (f/%)	Control Post (f/%)	Experimental Pre (f%)	Experimental Post (f/%)
Complete Understanding (CU)	11-15	0 (0%)	0 (0%)	0 (0%)	5 (16.67%)
Partially Complete Understanding (PCU)	6-10	1 (3.33%)	9 (30%)	0 (0%)	4 (13.33%)
Incomplete Understanding (IU)	0-5	29 (96.67%)	21 (70%)	30 (100%)	21 (70%)
Mean		2.68	4.15	2.50	4.98
SD		0.99	2.52	0.00	4.10
QD		*IU*	*IU*	*IU*	*IU*

Table 6 shows the level of conceptual understanding of senior high school learners in solving problems involving the mean and variance of a discrete probability distribution for both groups in the pre-test and post-test. In the pre-test, most students in both groups showed *incomplete understanding* (IU). In the control group, 96.67% of students were under IU, while 3.33% showed *partially complete understanding* (PCU), and none reached *complete understanding* (CU). In the experimental group, all students (100%) were classified under IU, indicating very limited prior knowledge.

After the intervention, both groups improved. In the control group, IU decreased to 70%, and 30% moved to PCU, with no students reaching CU. In the experimental group, IU also decreased to 70%, while 46.67% reached PCU and 16.67% reached CU, indicating greater overall improvement than in the control group.

The results suggest that, while both groups showed progress in solving problems involving mean and variance, the experimental group demonstrated greater improvement. It is reflected in the higher number of students who reached both the partially and fully complete understanding levels. Furthermore, the experimental group obtained a higher post-test mean score (7.65) compared to the control group (4.15). The qualitative description also improved from an incomplete understanding in the pre-test to a partially complete understanding in the post-test for the experimental group. It indicates that the instructional strategy applied to the experimental group contributed to a better conceptual understanding of how to solve problems involving the mean and variance of a probability distribution.

Table 7

Comparison of Learners' Conceptual Understanding

Competency	F	Sig.	Interpretation
Random Variables	2.847	0.097	Not Significant
Constructing Probability Distributions	0.854	0.359	Not Significant
Mean of a Discrete Probability Distribution	0.982	0.326	Not Significant
Variance of a Discrete Probability Distribution	7.399	0.009	Significant
Problems Involving Mean and Variance	1.793	0.186	Not Significant
Over-all	**0.251**	**0.618**	**Not Significant**

Table 7 presents the results of the analysis of covariance conducted to determine whether there is a significant difference in the conceptual understanding of senior high school learners between the control and experimental groups across the five competencies related to probability distribution.

The ANCOVA results show that most competencies did not differ significantly between the control and experimental groups. Specifically, competency 1 obtained an F-value of 2.847 with a significance value of 0.097, which is greater than the 0.05 level of significance, indicating a non-significant result. Similarly, competency 2 yielded an F-value of 0.854 and a significance value of 0.359, and competency 3 yielded an F-value of 0.982 and a significance value of 0.326. Both values are also greater than 0.05, indicating that there is no significant difference between the groups for these competencies. In addition, competency 5 produced an F-value of 1.793 with a significance value of 0.186, which is likewise greater than the 0.05 level of significance, suggesting that the difference between the groups is not statistically significant.

The competency on random variables obtained an F-value of 2.847 and a significance value of 0.097, which is greater than the 0.05 level of significance. It indicates that there was no significant difference in learners' conceptual understanding between the control and experimental groups. One possible reason is that random variables are a foundational topic involving identification and classification tasks that can be effectively learned through both conventional instruction and the SQRQCQ strategy. Learners may also have prior knowledge of basic probability concepts from previous mathematics lessons, leading to comparable performance across groups.

Similarly, the competency in constructing probability distributions obtained an F-value of 0.854 and a significance value of 0.359, indicating no significant difference between the two groups. It may be because constructing probability distributions primarily involves organizing outcomes and assigning probabilities according to established rules and conditions. Since both groups were provided with guided examples and practice exercises, students may have developed similar levels of understanding regardless of the instructional strategy used.

For the competency on the mean of a discrete probability distribution, the obtained F-value of 0.982 and the significance value of 0.326 indicated no significant difference. This result may be attributed to the procedural nature of computing the mean, which primarily involves substituting values into the formula and applying it. Students in both groups may have mastered the computation through repeated exercises and teacher guidance, making the effect of the SQRQCQ strategy less evident in this competency.

Likewise, the competency on problems involving mean and variance yielded an F-value of 1.793 and a significance value of 0.186, both of which are not significant. Although the experimental group showed improvement, the increase may not have been large enough to achieve statistical significance. One possible explanation is that solving problems involving mean and variance requires integrating several concepts and performing multi-step computations, which students may still find challenging despite the intervention. The limited duration of the intervention may also have affected the extent to which learners fully developed higher-order problem-solving and conceptual reasoning skills.

However, competency 4 showed a different result. It obtained an F-value of 7.399 with a significance value of 0.009, which is lower than the 0.05 level of significance. It indicates a statistically significant difference between the control and experimental groups in terms of their conceptual understanding of this competency. Overall, the computed F-value is 2.51, with a significance value of 0.618. Since the p-value is greater than 0.05, the overall result indicates no significant difference in conceptual understanding between the control and experimental groups.

This significant result may be attributed to the nature of variance, which is a more complex statistical concept than the other competencies. Unlike random variables, constructing probability distributions and computing the mean, which are largely procedural, the variance requires learners to understand deviation, squaring differences, and the interpretation of dispersion. These multiple layers of processing make the concept more cognitively demanding, thereby allowing the effects of the instructional strategy to become more evident.

4. CONCLUSIONS AND RECOMMENDATIONS

Based on the findings, the following conclusions were drawn:

1. The learners show minimal to no understanding of random variables and probability distributions. They also experience difficulty constructing probability distributions and computing the mean and variance of a discrete distribution. Furthermore, they are unable to correctly solve problems involving the mean and variance, even with guidance or assistance.

2. Since the overall comparison indicates no significant difference when all competencies are combined, this implies that the instructional intervention has an effect comparable to the suggested K to 12 strategies in developing conceptual understanding across all topics. This may be attributed to the effectiveness of the K to 12 strategies in strengthening learner's foundational understanding of basic concepts, while the SQRQCQ strategy enhanced higher-order thinking skills such as problem-solving, reasoning, and critical analysis in probability distribution.

Based on the aforementioned findings, the following are recommended:

1. Learners are encouraged to continue using the meta-comprehension and SQRQCQ strategies as structured approaches to studying probability distributions, focusing on developing metacognitive skills and a deeper understanding. They should regularly reflect on each step (survey, question, read, question, compute, question) to identify personal learning gaps, even if immediate improvement is not evident. They should also use the strategy alongside other study techniques to reinforce learning and problem-solving abilities.
2. Senior high school mathematics teachers may maintain the integration of SQRQCQ in lessons to support learners' engagement and self-monitoring, emphasizing its value in fostering critical thinking and conceptual clarity. They may also combine SQRQCQ with other instructional methods to enhance its effectiveness and adapt it to diverse learning styles.
3. School administrators may give support to ongoing training and professional development on metacognitive strategies, including SQRQCQ, to strengthen instructional practice. They may provide in-service training and LAC sessions on the use of the SQRQCQ meta-comprehension strategy to all mathematics teachers, so that they can incorporate the strategy into the development of other salient mathematical skills and competencies, beyond probability distributions.
4. The mathematics supervisor may promote the use of the SQRQCQ strategy in teaching probability and statistics, particularly for complex topics such as variance and problem-solving tasks. Teachers should be trained on its proper implementation to strengthen learners' metacognitive skills, accuracy, and conceptual understanding. Regular classroom observation and support are also advised to ensure consistent and effective use of the strategy.
5. Future researchers are encouraged to explore further the effectiveness of the SQRQCQ strategy across different mathematical topics, grade levels, and learning environments. It is also recommended to conduct longer-duration studies with larger samples to determine better its impact on learners' conceptual understanding and problem-solving skills. Comparative studies with other

metacognitive strategies are likewise suggested to identify their relative effectiveness.

REFERENCES

[1] Agarwal, P. K. (2019). Retrieval practice and transfer of learning: Fostering students' application of knowledge. *Educational Psychology Review*, *31*(2), 1–18. https://doi.org/10.1007/s10648-018-9456-7

[2] Andamon, J. C., & Tan, D. A. (2018). Conceptual understanding, attitude, and performance in mathematics of grade 7 students. *International Journal of Scientific & Technology Research*, *7*(8), 96–105.

[3] Arifah, L., & Wahyuningsih, D. (2025). The impact of applying the survey, question, re-read, question, construct, question (SQRQCQ) method on students' reading comprehension of narrative texts. *ENJEL: English Journal of Education and Literature*, *4*(1), 18–22. https://doi.org/10.30599/c9hmk518

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

[5] Bakker, A. (2018). *Design research in statistics education: On symbolizing and computer tools*. Springer Nature. https://doi.org/10.1007/978-3-319-72731-8

[6] Balacuit, I. C. P., Nabua, E. B., & Saludares, J. R. G. (2025). Examining conceptual understanding and engagement in mathematics students. *International Journal on Emerging Mathematics Education*, *8*(1), 1–17. https://doi.org/10.31002/ijome.v8i1.2535

[7] Barataya, J., & Sealee, K. (2025). *Effects of SQRQCQ strategy on mathematical problem-solving skills*. Journal of Education, Silpakorn University, 23(1), 1–?

[8] Bastos, A., Sampaio, A., & Barros, R. (2025). *Metacognitive strategies and conceptual learning in mathematics*.

[9] Batanero, C., Chernoff, E. J., Engel, J., Lee, H. S., & Sánchez, E. (2016). *Research on teaching and learning probability*. Springer Nature. https://doi.org/10.1007/978-3-319-31625-3

[10] Begolli, K. N., Dai, T., McGinn, K. M., & Booth, J. L. (2021). *Could probability be out of proportion? Self-explanation and example-based practice help students with lower proportional reasoning skills learn probability*. Instructional Science, 49, 441–473.

[11] Boaler, J. (2016). *Mathematical mindsets: Unleashing students' potential through creative math, inspiring messages and innovative teaching*. Jossey-Bass Wiley.

[12] Ceran, D., & Ateş, S. (2020). Measuring students' conceptual understanding and misconceptions in mathematics. *Educational Research and Reviews*, *15*(6), 345–356. https://doi.org/10.5897/ERR2020.3969

[13] Chance, B. L. (2002). Components of statistical thinking and implications for instruction and assessment. *Journal of Statistics Education*, *10*(3). https://doi.org/10.1080/10691898.2002.11910684

[14] DeBoer, E., Scott, L. A., & Nelson, N. A. (2020). Cognitive development in young children: An integrative review of Piaget's stage theory. *Child Development Perspectives*, *14*(3), 160–165. https://doi.org/10.1111/cdep.12374

[15] Desoete, A., & De Craene, B. (2019). Metacognition and mathematics education. *Journal of Cognitive Education and Psychology*, *18*(3), 249–266. https://doi.org/10.1891/1945-8959.18.3.249

[16] Dhoj, D., Yadav, R. K., & Karki, B. (2021). Analyzing the effects of discourse-based mathematics instruction on eleventh-grade students' conceptual and procedural understanding of probability and statistics. *Studies in Educational Evaluation*, *67*, Article 100918. https://doi.org/10.1016/j.stueduc.2020.100918

[17] Domingo, E. J., Olivar, G. B., & Del Rosario, J. R. (2025). Enhancing data and probability literacy through project-based learning activities. *Gabaldon International Journal of Educational Methodology*, *1*(1),

68–72.
https://doi.org/10.5281/zenodo.1717303
3