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Original Article

Probability Concepts: A Systematic Literature Review of Students' Learning Difficulties, Errors and Misconceptions

Emmanuel Appoh Andam[1*], *Francis Kwadwo Awuah*[1] *& William Obeng-Denteh*[1]

[1] Kwame Nkrumah University of Science and Technology, P. O. Box 25, Kumasi, Ghana.
[*] Author's Email: andamproject@gmail.com

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ABSTRACT

Human thinking development depends heavily on mathematics, especially when it comes to reasoning and problem-solving skills. Despite the fact that mathematics is currently used to solve problems in many disciplines, including science, it possesses unique characteristics known as probability and, more precisely, probability concepts. The review revealed that most students find probability concepts very difficult to learn and conceptualize. This study presents a systematic literature review on students learning difficulties on probability concepts in relation to the misconceptions and errors they encounter. The review analyses 32 empirically relevant studies published from 2014 to 2023, using the inclusion and exclusion search strategy. The 32 publications for this systematic review were chosen through an organised search process that made use of multiple databases, including EBSCO Academic Search Premier, Education Resources Information Centre (ERIC), SCOPUS, and Google Scholar. The findings from the systematic review revealed a number of misconceptions and errors which result in students' learning difficulties and their probability problem-solving. By recognizing these common errors, misconceptions and leveraging visual representations, educators can create targeted interventions to improve students' mastery of probability problem-solving skills and enhance their overall learning outcomes.

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INTRODUCTION

Probability, as discussed in various research papers, is indeed the branch of mathematics that assigns numerical values between zero and one to describe the likelihood of uncertain events (Fang *et al*., 2023). It serves as the foundation for statistical reasoning, emphasizing the importance of understanding unpredictability in data analysis (Ren & Wang, 2023; Julio, 2023). The concept of probability plays a crucial role in measurement theory, where it is viewed as a logic for modeling measurement processes and accounting for uncertainty, highlighting its significance beyond mere statistical applications (Rossi *et al.*, 2023).

Probability is a fundamental concept in mathematics that plays a crucial role in various fields, requiring learners to develop problem-solving skills and reasoning abilities (Hendricks & Olawale, 2023). Owing to the significance of probability, new mathematics curriculum for educational institutions is being developed globally (Hendricks & Olawale, 2023). For example, numerous nations, including Ghana, Spain, China, Germany, the United States, and others, have included the idea of probability in their mathematics curricula (Hokor *et al.*, 2022). Since the capacity to make decisions in the face of uncertainty is increasingly becoming a requirement for basic literacy around the globe, many nations have included probability as a core subject in their curricula (Bílek *et al.*, 2018; Morsanyi & Szucs, 2014).

Research in mathematics education has increasingly focused on addressing student misconceptions and errors in various mathematical domains (Bulut, 2023; Sadiah & Afriansyah, 2023; Hendricks & Olawale, 2023; Fardah & Palupi, 2023). Specifically, studies have delved into the realm of probability and probabilistic thinking, categorizing them into two types: understanding how people think and influencing how people think, investigated by psychologists and mathematics educators, respectively (Gorgun & Botelho, 2023). Traditional probability instruction, primarily centered on formal definitions, rules, and procedures, has been found ineffective in dispelling misconceptions about probability (Mutara & Makonye, 2016). The findings suggest that misconceptions persist across different grade levels, with varying frequencies and changes as students' progress, indicating a need for targeted interventions to address these persistent misunderstandings and errors.

According to Malaterre *et al.* (2023), misconceptions are formed when new information doesn't align with existing cognitive patterns, reinforcing faulty reasoning and becoming entrenched over time. Teachers play a crucial role in identifying and correcting misconceptions to facilitate conceptual change and enhance learning outcomes (Nadelson *et al.*, 2018). Consequently, even though students may grasp probability rules and processes and be able to compute accurate answers on mathematics tests, these same students frequently misunderstand fundamental principles and concepts, frequently ignoring the rules when making decisions regarding uncertain situations. Nevertheless, a number of studies from different theoretical perspectives seemed to support the claim that students frequently hold beliefs that hinder their comprehension of concepts in probability (Asberger *et al.*, 2021; Hendricks & Olawale, 2023; Ang & Shahrill, 2014; Batanero *et al.*, 2016).

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Given these circumstances, this systematic literature review seeks to delves into exploring students' errors and misconceptions associated with solving probability problems. As a result, this systematic literature review aims to synthesis and review students' misconceptions and errors, which result in their learning difficulties in probability concepts. It's important to identify the types of difficulties students' encounter when learning probability concepts and the reasons behind those difficulties (Memnun *et al.*, 2019). In sum, this review paper intended to critically analyze existing studies on misconceptions and errors in the teaching and learning of probability concepts. The review will also examine the learning difficulties students encounter in probability concepts as a result of the misconceptions and errors. This systematic literature review will be guided by the following research questions:

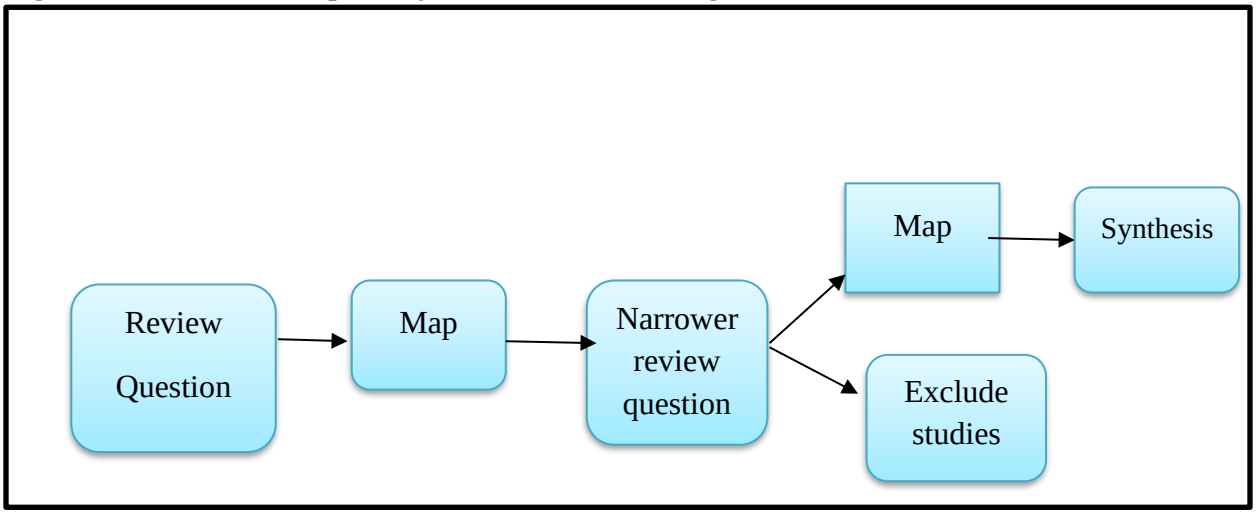
- What are learning difficulties encountered by students in probability concepts?
- What are students' errors in their probability problem-solving?
- What are the misconceptions that causes students learning difficulties in probability concepts?

MATERIALS AND METHOD

Inclusion Criterion

The successful conduct of systematic reviews is crucial for enhancing the rigor and relevance of research for informing policy decisions (Satnarine, 2023). Authors are expected to select suitable methodologies that align with the review questions and ensure that the evaluation of supporting evidence meets specific standards. By following structured approaches outlined in systematic review guidelines, researchers can enhance the transparency, reproducibility, and credibility of their reviews (Farhat *et al.*, 2022). Two stages are used in the conduct of systematic reviews, according to the Evidence for Policy and Practice Information and Coordinating Centre (EPPI-Centre, 2016). The initial phase entails the identification, enumeration, and characterization of extant research, encompassing its focus, design, and study setting (see figure 1).

Figure 1: Review with map and synthesis with narrowing of inclusion criteria



In the second stage, the selected evidence was carefully scrutinized and combined in order to address the research questions. The authors used Pickering *et al.* (2015)'s suggested review procedure for this systematic review. Pickering *et al.* (2015) state that the systematic literature review approach allows researchers to be methodical in the processes they employ to (i) search, (ii) survey, and (iii)

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choose research papers for carrying out a critical analysis of current research bodies. The authors were able to find relevant literature through this process, evaluate it critically, and then provide a brief summary of relevant research through this process. This section provides a brief summary of the critical actions the author performed to locate pertinent material and exclude irrelevant research studies.

Search Strategy

The study looked through institutional and electronic databases for pertinent research. Further research was also done based on the reference lists provided by a few selected articles. This was done in order to guarantee a broader audience and reduce the likelihood of prejudice. A detailed review of scholarly literature was conducted using an organised search process that made use of multiple databases, including EBSCO Academic Search Premier, Education Resources Information Centre (ERIC), SCOPUS, and Google Scholar. These were considered significant since they are the most widely-used databases in the education sector, which the study is a part of. The authors also had unrestricted access to each of these databases. One of the institutional databases examined was the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana repository. To locate all relevant articles, both electronic and manual searches made use of free text and thesaurus words. These include "mathematics education and probability," "learning probability," "problem-solving and probability," "students' difficulties in learning probability," "misconceptions in learning probability," "students' errors in learning probability," and "misconceptions and errors in probability problem-solving." To guarantee more thorough and comprehensive coverage of the comparison research on the probability problem-solving, each key word was individually run in each database. Since peer-reviewed papers are the most reliable sources of scientific information, only these were taken into account in the analysis.

Study Selection

In the first combined search of institutional and electronic databases, 412 articles were found. Duplicate copies of 283 articles were eliminated when the articles were exported to the open-source Zotero reference management software, which is used to handle bibliographic information and other research resources for the articles. This left 126 items for further assessment. Additional research was done on the papers based on their titles and abstracts, and 81 articles were selected for more examination. Thirty-two (32) studies were subjected to synthesis and meta-analysis in order to achieve the objectives of this systematic review.

Data Extraction Analysis

The authors extracted data and material for this systematic review from the downloaded publications that were chosen for the investigation using a bibliometric analysis table. The inclusion criteria defined for the systematic review served as the foundation for the creation of the bibliometric analysis table. Name of the author(s), year of publication, book, chapter, article, thesis, context (field of study), topic, contribution, research design, findings, and conclusion, as well as what the author(s) overlooked (delimitation) are among the variables. The other components of the data that were extracted from the publications were framed by the study questions. A free-text narrative data summary was produced for each study, and content analysis was utilized to examine it. The numerical data was analysed using the meta-analysis approach, which aggregates the results from various studies addressing the same topics. Subsequently, data from all the studies listed were used to formulate results and recommendations, which were based on this analysis approach.

FINDINGS

Student's Learning Difficulties in Probability Concepts

Students often face challenges in understanding probability concepts, as highlighted in various

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research papers. These difficulties range from struggles in solving mathematical problems related to probability theory (Astuti & Haryadi, 2023) to misconceptions and failures in applying basic probability concepts among students (Memnun *et al.*, 2019). Additionally, learners exhibit varying levels of misconceptions regarding probability, with some misconceptions persisting or growing as students' progress through grades (Hendricks & Olawale, 2023). For instance, a study by Anggara *et al.* (2018) revealed that students encounter obstacles in arranging sample spaces, events, and mathematical models related to probability problems, indicating incomplete or incorrect usage of quantitative information on probability concepts. The system literature review analyses the learning difficulties students encounter in their probability problem-solving according to the reviewed articles.

Hokor *et al.* (2022) identified three learning difficulties in their study. The difficulties outlined were conceptual difficulties, interpretation difficulties, and procedural difficulties. They ascertained that these difficulties among students were due to the misconceptions about the topic and advocated the need for teaching and learning activities to focus on addressing these learning difficulties. The conceptual difficulties identified by Hokor *et al.* (2022) were in line with another study by Baltaci (2016) which indicated that the learning difficulties encountered by students is as a result of lack of reasoning and strategies skills in their probability problem-solving. They concluded that, in as much as individual students have acquired different problem-solving skills, the lack of reasoning (conceptual) and strategic (procedural) skills will hinder their understanding of probability concepts and apply in it in real-life scenarios.

Another study by Ibrahim and Asiedu-Addo (2019) attributed the learning difficulties faced by college of education pre-service students to lack of procedural approach in their probability problem-solving. Their study revealed that the learning approach adopted by the pre-service students was formular-oriented and therefore were handicapped in the procedures to solving the problems. Dayal and Sharma (2021) shared similar views in their study which focused on the development of pre-service teachers probabilistic thinking in teacher education. According to Dayal and Sharma (2021) stated that equipping pre-service teachers with a strong procedural skill in the understanding of probability is essential to ensure they can guide their students effectively in problem-solving processes and facilitate meaningful learning experiences in mathematics. Pre-service teachers' understanding of probability concepts is critical for effectively teaching the subject to students, but research indicates they often struggle with fully grasping probability, underscoring the need to enhance their professional competency in this area (Sulfiah *et al.*, 2021). Studies show that pre-service teachers tend to have a more positive attitude towards statistics than probability, highlighting the need for targeted support and training to help them better understand and feel comfortable with probability concepts (Salifu & Dokurugu, 2022).

A study by Begolli *et al.* (2021) also identified proportional reasoning failures as constituting most errors in probability reasoning. The study analysed learning difficulties encountered by the students in the learning of probability concepts as a result of the proportional reasoning failures. Emphasizes was placed on the role of the proportional reasoning in attaining probabilistic knowledge and in addition to this, how to effectively intervene with students who have less proportional reasoning skills. The review explored the relationship between proportional reasoning, students' adversity quotient, and their ability to solve probability problems, demonstrating how different levels of adversity responses can influence proportional reasoning and impact problem-solving skills, highlighting the crucial role of proportional reasoning in understanding and applying probability concepts. They concluded by examining the contributions of student's proportional reasoning skills and example-based practices when learning probability concepts.

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Another study by Yusuf *et al.* (2022) on the challenges faced by college students identified three (3) categories of learning difficulties in solving probability word problems. Three categories of learning difficulties identified by the authors in the study were; unfamiliar with the meaning of the word, not well versed in the nature of the probability, and unable to identify the goal of the probability word problem. These difficulties were also similar to the ones identified and analysed in a study by Beitzel and Staley (2015) in this review. Beitzel and Staley (2015) posit that learning the concept of probability and solving the word problem of probability presents a challenge to the students. This is because students need to master the concept of probability, problem-solving process and understand the probability of problems simultaneously when solving probability word problems.

Brückler and Milin Šipuš (2023) in their study outlined several reasons for students' learning difficulties in probability: students' negative attitudes, lack of reasoning skills, readiness level, misconceptions, teacher, and age. According to Bursali and Ozdemir (2019), emerging evidence indicates that teachers' positive attitudes toward probability concepts play a critical role in effective probability instruction and student learning. Studies exploring attitudes towards probability and their impact on teaching and learning highlight the significance of fostering teachers' favorable perceptions for successful probability education (Estrada & Batanero, 2020; Estrada *et al.*, 2018). In mathematics education, attitudes are part of the affective domain, which also includes emotions and beliefs (Blanco *et al.*, 2022; Álvarez-Carrasco *et al.*, 2021). Research has shown a positive correlation between content knowledge and attitudes among students (Ruz *et al.*, 2021).

Students' self-regulated learning, according to Shodiqin *et al.* (2021) is another reason for student's learning difficulties in probability concepts in this systematic literature review. In the view of Shodiqin and Sukestiyarno (2021), in mathematical problem-solving, especially probability, one need self-regulated learning. Self-regulated learning is a multifaceted construct that involves the dynamic interactions between several interrelated control systems, including cognition, attention, metacognition, emotion, motivation, and volition (Lim & Yeo, 2021). The cognitive and constructive perspectives on the learning process place a strong emphasis on self-regulated learning (Çetin, 2017). Self-regulation can be understood as the self-developed feelings, thoughts, and behaviors that individuals use to achieve their desired goals (Gorgoz & Tican, 2020). The characteristics of learning independence reflect a highly individualized personality state, encompassing metacognitive processes where individuals purposefully design, implement, and evaluate their learning and themselves in a deliberate manner.

Student's Errors in their Probability Problem-solving

Students often make various errors when solving probability problems. Research has shown that these errors can stem from factors such as transformation errors, comprehension errors, process skill errors, and encoding errors (Sani & Rosnawati, 2022; Djam'an & Auliyah, 2022). Additionally, students may struggle with conceptual errors, fact errors, procedural errors, and technical errors when working on statistics problems (Lian *et al.*, 2021). Furthermore, students commonly face challenges related to basic statistical concepts, data interpretation, and selecting appropriate data representations when tackling statistics tasks (Huang *et al.*, 2021). In the context of probability, students frequently misunderstand problems, make computational errors, and struggle with procedural steps (Yusuf *et al.*, 2021). According to Triliana and Asih (2019), understanding these common errors in this systematic literature review can help educators tailor their teaching methods to address these specific challenges and enhance students' problem-solving abilities in probability.

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In a study by Salido and Dasari (2019), the authors analysed students' errors in solving probability problems based on Newton's theory. The Newman Error Analysis (NEA) theory provides an alternative approach to analyzing the types of errors made by students. According to Adu *et al.* (2015), the NEA theory offers a hierarchical framework that can be used to categorize different error types based on the level of a student's problem-solving abilities. The study findings revealed that the types of errors made by the students fell into the following categories: misunderstanding the problem, providing an incorrect final answer, and making mistakes in the problem-solving procedures. In line with the Newman Error Analysis (NEA) theory, these errors were categorized as comprehension errors, encoding errors, and process skills errors, as well as transformation errors.

Another study by Sani and Rosnawati (2022) on students' errors in probability story (word) problems in this systematic literature review also based it analysis of the errors on the revised Newman theory. The study findings revealed that the most prevalent types of errors made by students in solving story problems related to empirical and theoretical probabilities were transformation errors, comprehension errors, process skills errors, and encoding errors. The researchers attributed these errors to a range of factors, including students' lack of thoroughness, rushing through the problems, difficulties in understanding the questions, insufficient mastery of the material, forgetting formulas, hesitation in determining the appropriate formulas, failure to double-check their answers, and inability to properly communicate the final conclusions. Additionally, the researchers identified broader factors, such as interest, motivation, and societal influences, as contributing to the mistakes made by the students in the study.

In the studies of Brückler and Milin Šipuš (2023), outline several common errors students encounter in solving probability problems. The common errors encountered by students in solving probability problems include numerical and logical errors, biases, and fallacies related to conditional probability. These biases and fallacies in conditional probability were identified among pre-service mathematics teachers in the study. According to the authors, these errors were prevalent when problems had a context related to everyday experiences and information, leading to misconceptions and incorrect reasoning (Olgun & Isiksal-Bostan, 2019). The authors ascertained that the cause of student errors is the lack of student understanding of the prerequisite material for that solution in order to overcome similar errors, namely by always checking student understanding regarding prerequisite material before starting the lesson and choosing appropriate learning methods and strategies so that students can easily understand the material being taught.

Additionally, research by Hendricks and Olawale (2023) found that learners often struggle with misconceptions in probability, with some misconceptions fading with age while others persist or strengthen over time. Firat and Gürbüz (2022) highlighted that, teachers noted insufficient time allocated for conceptual learning in probability teaching, emphasizing the need to start teaching probability at an earlier age. Furthermore, Huang *et al.* (2021) identified that students commonly make mistakes in solving probability problems due to misunderstandings, computational errors, and procedural errors (Yusuf *et al.*, 2021). These findings collectively underscore the challenges students face in mastering probability concepts and the importance of targeted interventions to address these issues.

Understanding common errors in solving probability problems, such as transformation errors, comprehension errors, process skill errors, and encoding errors, as highlighted in the research by Sani and Rosnawati (2022) and other researchers, can assist educators in tailoring their teaching methods to address these challenges effectively. Additionally, the importance of visual

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representations in teaching probabilities, as emphasized by Zorzos and Avgerinos (2023), can provide valuable insights into enhancing students' problem-solving abilities. Moreover, the difficulties students face in understanding, choosing appropriate strategies, and computational processes when solving probabilistic problems, as identified by Arum *et al.* (2018), underscore the need for educators to optimize probabilistic thinking through well-planned teaching strategies. By recognizing these common errors and leveraging visual representations, educators can create targeted interventions to improve students' mastery of probability problem-solving skills and enhance their overall learning outcomes (Sihotang & Zuhri, 2022; Yusuf *et al*., 2020; Huang *et al.*, 2021; Hull *et al.*, 2021).

Misconceptions Causing Students' Learning Difficulties in Probability Concepts

This systematic literature review also sought to take a look at the misconceptions that cause students' difficulties in learning probability. According to Hendricks and Olawale (2023), misconceptions in probability problems are indeed common among students, contributing to challenges in grasping fundamental probability concepts. Studies have shown that learners often struggle with understanding probability, with misconceptions varying across grade levels and persisting despite progression (Gallagher, 2023). A literature review of the of the articles in the systematic review highlighted several of these misconceptions leading to the students' learning difficulties in probability. Guerra-Reyes *et al.* (2024) defined students' misconceptions as the conceptions that results into a systematic misunderstanding that results in a regular pattern of mistakes. Misconceptions can also be thought of as beliefs about how things ought to be done that are false in and of themselves.

For instance, Hokor *et al.* (2022) discovered that the most common misconceptions about probability were primarily associated with misperceptions regarding equiprobability bias, representativeness bias, negative and positive recency effects, result orientation bias, and belief bias. They also claim that conceptual difficulties, interpretation difficulties, procedural difficulties, and misconceptions about procedural steps are among the common misconceptions about probability. Another study by Paul and Hlanganipai (2014) examined students' misconceptions about probability in three grades (10, 11, and 12) in South Africa. In their findings, they discovered that equiprobability bias is the most widespread misunderstanding across all of the classes. The challenging issues regarding these misconceptions according Guerra-Reyes *et al.* (2024) is that, majority of the students' have difficulty in letting go them due the fact that these false concepts have become firmly grounded in their minds.

Begolli *et al.* (2021) found that proportional reasoning failure is the primary cause of misconceptions, leading to errors, in probabilistic reasoning among students. They found limited empirical evidence on proportional reasoning's role in achieving higher probabilistic knowledge. They suggested interventions for students with less proportional reasoning skills. Again, the study be Yusuf *et al.*'s (2022) revealed that students often struggle with probability problems, contributing to low academic achievement. The researchers identified three main difficulties: unfamiliarity with word meanings, lack of probability knowledge, and difficulty identifying goal. The study found students struggled with understanding terms like "subsequent," "provided," and "perfect square number," and the basics of probability. They also struggled with the rule of probability and the task's objective. These difficulties were identified as significant challenges in their understanding of the subject matter.

Another study by Astuti *et al.* (2020) in looking at the students' misconceptions in higher education mathematical probability also identified several misconceptions leading to students' errors. The researchers identified for four misconceptions made

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by the students in solving probability problems: students' errors in interpreting questions, students' errors in the procedure of proving the probability theorems, students' misconceptions in the application of Bayes' rules in when solving the probability problems and the errors in calculating the possibility of an event by the students. The researchers analysed the students' errors based on the error analysis method developed by Abdullah *et al.* (2015). According to Diantik *et al.* (2022), pupils struggle with probability problem-solving because they have a poor grasp of fundamental information and theoretical concepts. They were of the view that, one of the reasons why students make mistakes when handling probability issues is a lack of fundamental concepts. Some pupils' errors were brought on by their inability to comprehend the questions command, using Bayes' rules, and do combined calculations (Phonapichat *et al.*, 2014; Budgett & Pfannkuch, 2019; Ang & Shahrill, 2014).

Ang and Shahrill (2014) in their study outlined *representativeness*, *equiprobability bias*, *beliefs* and *human control* as the misconceptions that results in students' learning difficulties in probability. These misconceptions are in line with the misconceptions listed by Hokor *et al.* (2022) in this systematic literature review. In the study, the authors referred to representativeness as the tendency of students to incorrectly think that samples which correspond to the population distribution are more probable than samples which do not. For example, in tossing a coin, students with this misperception will think that a series of coin tosses that has approximately equal numbers of heads and tails is more probable than a series with many more tails than heads. They were of the view that students with equiprobability bias misconception tend to assume that random events are equally probable by nature. In the context of the belief misconception, Goulding *et al.* (2022) posit that a number of children think that eventual outcome of an event depends on a force which is beyond their control. Sometimes this force is God or some other force such as wind, other times luck or wishes (Bramley *et al.*, 2022).

Research from various studies indicates that student's understanding of randomness and probability, particularly in relation to random generators like dice, coins, and spinners, can vary significantly. Some student tends to believe that the outcomes of these devices depend on how they are thrown or handled, showcasing a misconception about the true nature of randomness (Supply *et al.*, 2023; Kingston & Twohill, 2022). It is crucial to identify if students have any misconceptions about probability concepts during the initial stages of their schooling. The findings from this study can help teachers become more aware of any misunderstandings their students may have regarding probability, and allow them to address these issues before the students move on to pre-university and university-level coursework. This is important so that the students do not carry these misconceptions with them to higher levels of education.

CONCLUSION

Misconceptions in probability problem-solving is prevalent among students, leading to difficulties in learning the concepts. These misconceptions often stem from various sources such as classificational errors, correlational misunderstandings, and theoretical misconceptions. Students frequently struggle with encoding errors, language barriers, and translating mathematical expressions, hindering their ability to solve problems accurately. This systematic literature review analyzed misconceptions and errors in probability problem-solving, revealing prevalent fallacies like equiprobability bias, representativeness bias, negative recency effects, result orientation bias, and belief bias, along with conceptual, interpretation, and procedural difficulties (Hokor *et al.*, 2022). Begolli *et al.* (2021) and Yusuf *et al.* (2022) found that students often struggle with probabilistic reasoning due to proportional reasoning failure and word problems, categorized into three difficulties as follows: unfamiliar with the meaning of the words, not well versed in the nature of the probability, and

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unable to identify the goal of the probability word problem. Sani and Rosnawati' s (2022) study identified four errors contributing to poor academic performance in probability problems: encoding, transformation, comprehension, and process-skill errors.

Misconceptions, such as interpreting questions, proving probability theorems, applying Bayes' rules, and calculating event probabilities, also contribute to these errors (Astuti *et al.*, 2020). Students' misconceptions and poor problem-solving abilities contribute to their errors in probability questions, often due to their inability to comprehend the question command and probability concepts. Many studies in the field of probability problem-solving have focused on students' skills while solving problems. Thus, this study is expected to contribute to the limited empirical studies in identifying weaknesses or difficulties faced by students while solving problems. This is because such studies provide information on the difficulties faced by students in learning and teaching probability, as well as contribute ideas to instructors in developing the pedagogical techniques practiced. Instructors can curate methods and approaches in addressing the issue of student difficulties in the mathematical problem-solving process before, during, or even after the learning and teaching sessions are implemented. From this research study, the authors were able to identify students with misconceptions on Probability and understand their difficulties when learning Probability. However, the students' problems may remain in their learning process and progress unless steps of treating these problems can be implemented.

Understanding common errors in probability problem-solving, as highlighted by Sani and Rosnawati (2022), can significantly benefit educators in tailoring their teaching methods to address these challenges effectively. By recognizing the various types of errors students make, such as reading, comprehension, transformation, process skill, and encoding errors, educators can design instructional strategies that specifically target these areas of weakness. Additionally, insights from studies by Sani and Rosnawati (2022), Aziz and Rosli (2021), Salido and Dasari (2019), and Begolli *et al.* (2021) emphasize the importance of considering factors like students' attitudes, learning environments, and basic knowledge in developing statistical literacy, which is crucial for enhancing students' problem-solving abilities in probability. By incorporating error analysis and conceptual literacy development strategies into their teaching approaches, educators can better support students in mastering probabilistic concepts and improving their overall problem-solving skills.

Limitations of the Study

Using a review methodology that only includes relevant research articles published between 2014 and 2023 may introduce potential publication bias. This approach is unlikely to capture studies produced before or after the specified timeframe. Additionally, limiting searches for relevant research to only English-language studies could introduce bias. Restricting reviews to only research articles published in peer-reviewed journals could also subject the review to publication bias, as this strategy is unlikely to find studies that have not been published in peer-reviewed outlets. Additionally, this systematic literature review revealed that studies on an intervention model to help students understand probability concepts is limited.

Suggestions for Future Studies

Future studies can expand the scope of their literature reviews to include more relevant sources beyond just peer-reviewed journal articles. This could involve incorporating "grey literature" such as conference proceedings, theses, reports, bibliographies, and records of ongoing research. This broader approach would provide a more comprehensive overview of the available evidence on the topic. Additionally, future studies can expand their database searches to include collections of

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non-English language studies related to probability concepts. This would help capture a wider range of relevant research that may not be published in English-language journals. This systematic literature review also revealed that studies on proposed interventional models to enhance students understanding of probability concepts is limited. Also, future studies should review and focus on studies with interventional models that will promote students conceptual understanding of probability concepts in order to improve their problem-solving skills, reduce their errors and enhance their conceptual knowledge.

Competing Interests

Authors have declared that no competing interests exist.

REFERENCES

Abdullah, A. H., Abidin, N. L. Z., & Ali, M. (2015). Analysis of students' errors in solving Higher Order Thinking Skills (HOTS) problems for the topic of fraction. *Asian Social Science*, *11*(21), 133-142.

Adu, E., Assuah, C. K., & Asiedu-Addo, S. K. (2015). Students' errors in solving linear equation word problems: Case study of a Ghanaian senior high school. *African Journal of Educational Studies in Mathematics and Sciences*, *11*, 17-30.

Álvarez-Carrasco, D. A., Barahona-Rivera, N. Y., & Godoy-Ponce, O. A. (2021). Teachers' affective mastery in solving mathematical problems. *Electronic Journal of Knowledge, Knowledge and Practice*, *4*(1), 70-85.

Ang, L. H., & Shahrill, M. (2014). Identifying students' specific misconceptions in learning probability. *International Journal of Probability and Statistics*, *3*(2), 23-29.

Anggara, B., Priatna, N., & Juandi, D. (2018). Learning difficulties of senior high school students based on probability understanding levels. In *Journal of Physics: Conference Series* (Vol. 1013, No. 1, p. 012116). IOP Publishing.

Arum, D. P., Kusmayadi, T. A., & Pramudya, I. (2018). Students' difficulties in probabilistic problem-solving. In *Journal of Physics: Conference Series* (Vol. 983, No. 1, p. 012098). IOP Publishing.

Asberger, J., Thomm, E., & Bauer, J. (2021). On predictors of misconceptions about educational topics: a case of topic specificity. *Plos one*, *16*(12), e0259878.

Astuti, D., Anggraeni, L., & Setyawan, F. (2020). Mathematical probability: Student's misconception in higher education. In *Journal of Physics: Conference Series* (Vol. 1613, No. 1, p. 012009). IOP Publishing.

Astuti, R., &; Haryadi, R. (2023). Analysis of Student Difficulties in Solving Mathematical Understanding Problems in the Probability Theory Course. *AXIOM: Journal of Education and Mathematics*, *11*(2), 218-227.

Aziz, A. M., & Rosli, R. (2021). A systematic literature review on developing students' statistical literacy skills. In *Journal of Physics: Conference Series* (Vol. 1806, No. 1, p. 012102). IOP Publishing.

Baltaci, S. (2016). Examination of Gifted Students' Probability Problem Solving Process in Terms of Mathematical Thinking. *Malaysian Online Journal of Educational Technology*, *4*(4), 18-35.

Batanero, C., Chernoff, E. J., Engel, J., Lee, H. S., & Sánchez, E. (2016). Research on Teaching and Learning Probability. *The Proceedings of the 12th International Congress on Mathematical Education.* New York, NY: Springer.

Begolli, K. N., Dai, T., McGinn, K. M., & Booth, J. L. (2021). Could probability be out of

Article DOI : https://doi.org/10.37284/eajass.8.2.3008

proportion? Self-explanation and example-based practice help students with lower proportional reasoning skills learn probability. *Instructional Science*, *49*, pp.441-473.

Beitzel, B. D., & Staley, R. K. (2015). The efficacy of using diagrams when solving probability word problems in college. *The Journal of Experimental Education*, *83*(1), 130-145.

Bílek, J., Nedoma, J., & Jirásek, M. (2018). Representativeness heuristics: A literature review of its impacts on the quality of decision-making. *Scientific papers of the University of Pardubice. Series D, Faculty of Economics and Administration. 43/2018*.

Blanco, T. F., Gorgal-Romarís, A., Núñez-García, C., & Sequeiros, P. G. (2022). Digital Education to Approach the Affective Domain in Mathematics Learning. In *Inclusive Digital Education* (pp. 47-69). Cham: Springer International Publishing.

Bramley, N. R., Jones, A., Gureckis, T. M., & Ruggeri, A. (2022). Children's failure to control variables may reflect adaptive decision-making. *Psychonomic Bulletin & Review*, *29*(6), 2314-2324.

Brückler, F. M., & Šipuš, Ž. M. (2023). Pre-service mathematics teachers' understanding of conditional probability in the context of the COVID-19 pandemic. *European Journal of Science and Mathematics Education*, *11*(1), pp.89-104.

Budgett, S., & Pfannkuch, M. (2019). Visualizing chance: tackling conditional probability misconceptions. *Topics and trends in current statistics education research: International perspectives*, 3-25.

Bulut, A. S. (2023). Mathematics Teachers' Knowledge on Misconceptions and Solution Suggestions: Ratio-Proportion Topic. *International Journal of Educational Research Review*, *8*(3), 596-609.

Bursalı, G. G., & Gökkurt-Özdemir, B. (2019). Instructional explanations of mathematics teachers and preservice teachers on misconceptions: The subject of probability. *Journal of computer and education research*, *7*(14), 642-672.

Çetin, B. (2017). The Influence of Pintrich's Self-Regulated Learning Model on Elementary Teacher Candidates in a Life Science Course. *Journal of Education and Training Studies*, *5*(8), 30-36.

Dayal, H., & Sharma, S. (2021). Secondary Pre-Service Teachers' Views on Using Games in Teaching Probability: An International Collaboration. *Mathematics Education Research Group of Australasia*.

Djam'an, N., Sahid, S., & Auliyah, F. (2022). Analysis of Student Errors in Solving Statistics Problems in terms of Mathematical Ability. *SAINSMAT: Journal of Applied Sciences, Mathematics, and Its Education*, *11*(2), 96-104.

Estrada, A., & Batanero, C. D. (2020). Prospective primary school teachers' attitudes towards probability and its teaching. *International Electronic Journal of Mathematics Education*, 15(1), 1-14.

Estrada, A., Batanero, C., & Díaz, C. (2018). Exploring teachers' attitudes towards probability and its teaching. *Teaching and learning stochastics: Advances in probability education research*, 313-332.

Evidence for Policy and Practice Information and Coordinating Centre (EPPI-Centre) (2016). Terms of reference for Systematic reviews. Institute of Education, Department for International Development, EPPI Centre.

Article DOI : https://doi.org/10.37284/eajass.8.2.3008

Fang, Z., Tan, K., & Wang, Z. (2023). Fundamental results in probability theory. *Highlights in Science, Engineering and Technology*, *49*, 464-469.

Fardah, D. K., & Palupi, E. L. W. (2023). Misconceptions of Prospective Mathematics Teacher in Linear Equations System. *Prima: Journal of Mathematics Education*, *7*(1), 100-111.

Farhat, N., Tsaioun, K., Saunders-Hastings, P., Morgan, R. L., Ramoju, S., Hartung, T., & Krewski, D. (2022). Systematic review in evidence-based risk assessment. *ALTEX-Alternatives to animal experimentation*, *39*(3), 463-479.

Fırat, S., & Gürbüz, R. (2022). Evaluation of the Probability Teaching-Learning Process Based on Mathematics Teachers' Views. *Abant İzzet Baysal University Faculty of Education Journal*, *22(4)*, 1621-1641.

Gallagher, K. (2023). Overcoming misconceptions about probability a review of David J. hand's the improbability principle. *The Mathematics Enthusiast*, *20*(1), 217-224.

Gorgoz, S., & Tican, C. (2020). Investigation of Middle School Students' Self-Regulation Skills and Vocabulary Learning Strategies in Foreign Language. *International Journal of Educational Methodology*, *6*(1), 25-42.

Gorgun, G., & Botelho, A. F. (2023). Enhancing the Automatic Identification of Common Math Misconceptions Using Natural Language Processing. In *International Conference on Artificial Intelligence in Education* (pp. 302-307). Cham: Springer Nature Switzerland.

Goulding, B. W., Stonehouse, E. E., & Friedman, O. (2022). Causal knowledge and children's possibility judgments. *Child Development*, *93*(3), 794-803.

Hendricks, W., & Olawale, B. E. (2023). Mathematical Probability: Learner's misconception in a selected South African School. *Infinity Journal*, *12*(1), 165-178.

Hokor, E. K., Apawu, J., Owusu-Ansah, N. A., & Agormor, S. (2022). Preservice Teachers' Misconceptions in Solving Probabilistic Problems. *Pedagogical Research*, *7*(1), 1 – 16.

Huang, Y., Zhou, Y., & Li, Y. (2021). Analysis of Students' Error in Solving Probability Problem: A Case Study in Guangxi. *INOMATIKA*, *3*(1), 1-15.

Hull, M. M., Jansky, A., & Hopf, M. (2021). Probability-related naïve ideas across physics topics. *Studies in Science Education*, *57*(1), 45-83.

Ibrahim, B. H., & Asiedu-Addo, S. (2019). Effect of problem-based learning on Colleges of Education students' achievement in probability and attitude towards solving probability related problems. *African Journal of Educational Studies in Mathematics and Sciences*, *15*(2), pp.155-168.

Julio, A. B. (2023). The General Theory of the Probability. *Journal of Modern Physics*, *14*(08), 1157-1166.

Kingston, M., & Twohill, A. (2022). Young children's use of subjective thinking in response to probabilistic tasks. *Statistics Education Research Journal*, *21*(3), 5-5.

Lian, L. H., Yew, W. T., & Meng, C. C. (2022). Assessing Lower Secondary School Students' Common Errors in Statistics. *Pertanika Journal of Social Sciences & Humanities*, *30*(3).

Lim, S. L., & Yeo, K. J. (2021). A systematic review of the relationship between motivational constructs and self-regulated learning. *Int. J. Eval. Res. Educ. ISSN*, *2252*, 8822.

Article DOI : https://doi.org/10.37284/eajass.8.2.3008

Malaterre, C., Javaux, E. J., & López-García, P. (2023). Misconceptions in Science. *Perspectives on Science*, *31*(6), 717-743.

Memnun, D. S., Ozbilen, O., & Dinc, E. (2019). A Qualitative Research on the Difficulties and Failures about Probability Concepts of High School Students. *Journal of Educational Issues*, *5*(1), 1-19.

Morsanyi, K., & Szucs, D. (2015). Intuition in mathematical and probabilistic reasoning. *Oxfo rd library of psychology. The Oxford handbook of numerical cognition*, 180-200.

Mutara, L., & Makonye, J. (2016). Learners' use of probability models in answering probability tasks in South Africa. In *Promoting understanding of statistics about society, Proceedings of the 13th International Conference of Mathematical Education, July* (pp. 24-31).

Nadelson, L. S., Heddy, B. C., Jones, S., Taasoobshirazi, G., & Johnson, M. (2018). Conceptual Change in Science Teaching and Learning: Introducing the Dynamic Model of Conceptual Change. *International Journal of Educational Psychology, 7(2),* 151-195.

Olgun, B., & Isiksal-Bostan, M. (2019). The influence of the context of conditional probability problems on probabilistic thinking: A case study with teacher candidates. *Eleventh Congress of the European Society for Research in Mathematics Education (CERME11)*, Utrecht University, Utrecht, Netherlands. ffhal-02412821f.

Paul, M., & Hlanganipai, N. (2014). The nature of misconceptions and cognitive obstacles faced by secondary school mathematics students in understanding probability: A case study of selected Polokwane secondary schools. *Mediterranean Journal of Social Sciences*, *5*(8), 446-455.

Phonapichat, P., Wongwanich, S., & Sujiva, S. (2014). An analysis of elementary school students' difficulties in mathematical problem solving. *Procedia-social and behavioral sciences*, *116*, 3169-3174.

Pickering, C., Grignon, J., Steven, R., Guitart, D., & Byrne, J. (2015). Publishing not perishing: How research students transition from novice to knowledgeable using systematic quantitative literature reviews. *Studies in Higher Education*, *40*(10), 1756-1769.

Ren, J., & Wang, H. (2023). *Mathematical methods in data science*. Elsevier.

Rossi, G. B., Crenna, F., & Berardengo, M. (2023). Probability theory as a logic for modelling the measurement process. *Acta IMEKO*, *12*(2), 1-5.

Ruz, F., Chance, B., Medina, E., & Contreras, J. M. (2021). Content knowledge and attitudes towards stochastics and its teaching in pre-service Chilean mathematics teachers. *Statistics Education Research Journal*, *20*(1), 5-5.

Sadiah, D. S., & Afriansyah, E. A. (2023). Student misconceptions are reviewed from the level of problem solving in fractional operation material. *Journal of Mathematics Learning Innovation: PowerMathEdu*, *2*(1), 31-44.

Salido, A., & Dasari, D. (2019), April. Students' errors in solving probability problems viewed by learning style. In *Journal of Physics: Conference Series* (Vol. 1211, No. 1, p. 012067). IOP Publishing.

Salifu, A. S., & Dokurugu, M. E. (2022). The Relationship Between Pre-Service Teachers' Attitude Towards Statistics and Attitude Towards Probability. *Infinity Journal*, *11*(1), 115-132.

Sani, D. N., & Rosnawati, R. (2022). Students' Error Analysis in Solving Probability Story Questions Based on Revised Newman

Article DOI : https://doi.org/10.37284/eajass.8.2.3008

Theorem. *Journal of Mathematics Education (JUPITEK)*, *5*(2), pp.123-131.

Satnarine, T. (2023). Systematic review methodology: conducting high-quality reviews and understanding their significance in evidence-based practice. *Journal for International Medical Graduates*, *2*(1).

Shodiqin, A., & Sukestiyarno, Y. L. (2021). Probabilistic Thinking Profile of Mathematics Teacher Candidates in Problem Solving Based on Self-Regulated Learning. *European Journal of Educational Research*, *10*(3), 1199-1213.

Sihotang, S. F., & Zuhri, Z. (2022). The Effect of Statistics and Probability Learning Model Improvement on Student Learning Outcomes. *Alifmatika: Journal of Mathematics Education and Learning*, *4*(1), 65-81.

Sulfiah, S. K., Cholily, Y. M., & Subaidi, A. (2021). Professional Competency: Pre-Service Mathematics Teachers' Understanding toward Probability Concept. *Journal of Research and Advances in Mathematics Education*, *6*(3), 206-220.

Supply, A. S., Wijns, N., Van Dooren, W., & Onghena, P. (2023). It is probably a pattern: does spontaneous focusing on regularities in preschool predict reasoning about randomness four years later? *Educational Studies in Mathematics*, *112*(1), 3-24.

Triliana, T., & Asih, E. C. M. (2019l). Analysis of students' errors in solving probability based on Newman's error analysis. In *Journal of Physics: Conference Series* (Vol. 1211, No. 1, p. 012061). IOP Publishing.

Yusuf, M., Rahim, S. S. A., & Eu, L. K. (2020). Solving Strategies of Probability Word Problems Among College Students. *MOJES: Malaysian Online Journal of Educational Sciences*, *8*(2), 28-35.

Yusuf, M., Rahim, S. S. A., & Eu, L. K. (2021). Obstacles faced by college students in solving probability word problems. *Journal of Mathematics Education*, *15*(1), 83-90.

Yusuf, M., Rahim, S. S. A., & Eu, L. K. (2022). Challenges Faced by College Students in Solving Probability of Event Problems. *MOJES: Malaysian Online Journal of Educational Sciences*, *10*(3), pp.13-19.

Zorzos, M., & Avgerinos, E. (2023). Research on visualization in probability problem solving. *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(4), em2247.

