

Implementation of Fisher-Yates Shuffle Algorithm in Mobile-Based Vocabulary Learning Game for Children with Disabilities

Khaidir Rahman Natsir^{1,a,*}; **Tamra**^{2,a}; **Muhammad Rizal H**^{3,c}; **First wanita**^{4,d}; **Mursalim**^{5,e}

¹ Department of Information Technology Education, University Teknologi Akba Makassar, Makassar, Indonesia

^{2,3,5} Department of Informatics Engineering, Universitas Teknologi Akba Makassar, Indonesia

⁴ Department of Computer Science, Universitas Teknologi Akba Makassar, Indonesia

^akhaidir@akba.ac.id; ^btamra@unitama.ac.id; ^crizal@unitama.ac.id; ^dfirst@akba.ac.id; ^emursalim@unitama.ac.id

* Corresponding author

Abstract

Children with disabilities face significant challenges in vocabulary acquisition, necessitating the development of specialized educational technologies that accommodate their unique learning characteristics. This study aims to implement the Fisher-Yates shuffle algorithm in a mobile-based vocabulary learning game specifically designed for children with disabilities. The unbiased nature of the randomization was empirically validated through chi-square goodness-of-fit testing across 10,000 simulation trials ($\chi^2(9) = 8.47, p = 0.487$), confirming uniformly distributed content sequencing to promote authentic vocabulary comprehension. This research employed the Multimedia Development Life Cycle methodology, encompassing concept definition, design, material collection, assembly, testing, and distribution phases. The Fisher-Yates shuffle algorithm was implemented following the modern Durstenfeld variant, operating through backward iteration, generating random indices, and performing in-place element swapping. Algorithm validation was conducted through simulation calculations and chi-square goodness-of-fit statistical testing across ten thousand randomization trials. The application "Tebak Kosakata" successfully integrates the randomization algorithm with an accessible user interface, featuring multimodal content presentation, immediate positive feedback mechanisms, and cumulative scoring systems. Simulation calculations confirmed that each vocabulary item maintains an equal probability for occupying any position in the final sequence. Statistical validation yielded a chi-square value of 8.47 with nine degrees of freedom and a probability value of 0.487, confirming uniformly distributed randomization without detectable bias. The algorithm achieves optimal computational efficiency with linear time complexity and constant auxiliary space complexity. The randomization of question sequences and answer option positions effectively prevents pattern-based response strategies, encouraging authentic vocabulary learning rather than positional memorization. This study establishes that the Fisher-Yates shuffle algorithm constitutes an effective mechanism for implementing unbiased randomization in educational games for children with disabilities. While the present investigation focuses on system development and algorithmic validation rather than measuring learning effectiveness, it bridges computational algorithm theory with special education pedagogy and provides a replicable methodological framework for future empirical evaluation of learning outcomes.

Keywords— *Fisher-Yates shuffle algorithm, vocabulary learning, mobile game, children with disabilities, educational technology, randomization*

1. Introduction

The landscape of special education has undergone significant transformation with the proliferation of digital technologies, particularly mobile applications that offer unprecedented opportunities for addressing the unique learning needs of children with disabilities (Pradeep, 2023; Qahmash, 2018; Zhang & Wang, 2024). Children with disabilities, encompassing a broad spectrum of conditions including intellectual disabilities, autism spectrum disorder, and learning disabilities, often encounter substantial challenges in vocabulary acquisition due to limitations in cognitive processing, working memory, and attention regulation (Tübele & Landrāte, 2021). These challenges necessitate innovative pedagogical approaches that can accommodate diverse learning styles while maintaining engagement and motivation throughout the educational process.

Vocabulary development constitutes a fundamental pillar of language acquisition and communication competence, serving as a prerequisite for academic achievement and social participation among children with disabilities (Lee, 2023; O'Connor et al., 2019). Research has consistently demonstrated that children with intellectual disabilities possess significantly limited active vocabularies compared to their typically developing peers, with notable discrepancies between receptive and expressive language capabilities (Tübele & Landrāte, 2021; Vandereet et al., 2011). The speech patterns of these children predominantly comprise basic nouns and everyday verbs, with adjectives, adverbs, and conjunctions appearing infrequently in their linguistic repertoire. This vocabulary deficit not only impedes academic progress but also constrains social interaction and diminishes quality of life, thereby underscoring the imperative for effective intervention strategies.

The emergence of game-based learning has garnered substantial attention within special education contexts as a promising modality for facilitating skill acquisition among learners with disabilities (Mokobane, 2025; Saridaki & Mourlas, 2013). Game-based learning originated from research initiatives in the 1950s and has evolved considerably with the popularization of electronic games and the transformation of educational paradigms (Amiruddin et al., 2020; Marques & Pombo, 2021; Okta Riyandi et al., 2023). Educational games have demonstrated efficacy in enhancing various competencies, including cognitive skills, behavioral outcomes, and academic performance across diverse disability categories (Chakraborty et al., 2021; Mokobane, 2025; Papanastasiou et al., 2022). The intrinsic motivational properties of games, combined with their capacity to provide immediate feedback and repetitive practice opportunities, align particularly well with the learning characteristics of children with disabilities who require multiple exposures to content and scaffolded instruction.

Mobile technology has emerged as an especially promising platform for delivering educational interventions to children with disabilities due to its accessibility, portability, and capacity for individualized learning experiences (Ismaili & Ibrahim, 2016; Wang et al., 2024). The ubiquity of smartphones and tablets has democratized access to educational resources, enabling caregivers and educators to implement learning activities across multiple settings beyond traditional classroom environments. Systematic reviews have documented the effectiveness of mobile applications in supporting vocabulary development, literacy skills, and communication competencies among children with various disabilities (Davis & Sweeney, 2015; Ganz et al., 2017). Furthermore, mobile platforms facilitate the integration of multimedia elements, including visual stimuli, auditory feedback, and interactive components, which have been shown to enhance learning outcomes for children with special educational needs.

The gamification of educational content represents a pedagogical strategy that has demonstrated substantial benefits for learners with disabilities by increasing engagement, motivation, and learning persistence (Baumuratova et al., 2025; Magnago & Nunes, 2024). Gamification incorporates game design elements such as points, badges, levels, and rewards into

non-game contexts to enhance user experience and achieve educational objectives. Research has established that gamification positively impacts children's satisfaction with learning activities while enhancing various skills including cognitive abilities, behavioral competencies, and life skills (Carcelén-Fraile, 2025; Fadhli et al., 2020). For children with disabilities specifically, gamified learning environments have been shown to improve emotional regulation, increase time on task, and promote mastery motivation, all of which contribute to more effective learning outcomes.

A critical consideration in the design of educational games pertains to the implementation of question randomization mechanisms, which serve multiple pedagogical and assessment functions (Devnanza et al., 2025; Rubio-Arreaz, 2021). Randomization of learning content prevents predictability in question sequences, thereby encouraging genuine engagement with material rather than memorization of response patterns. The Fisher-Yates shuffle algorithm, also known as the Knuth shuffle, represents a computationally efficient method for generating unbiased random permutations of finite sequences with $O(n)$ time complexity (Kartal, 2024). This algorithm produces each possible permutation with equal probability, ensuring fairness in the distribution of learning content while preventing duplicate question presentations that could diminish the educational value of game sessions.

The application of the Fisher-Yates shuffle algorithm in educational game contexts has been documented across various implementations, including quiz applications, language learning platforms, and assessment systems (Rohmah et al., 2020). Research has demonstrated that proper implementation of this randomization algorithm enhances test validity and reliability while reducing opportunities for content sharing among users (Hickman et al., 2023). In vocabulary learning games specifically, randomization ensures that learners encounter words in varied sequences across multiple sessions, promoting distributed practice and reducing the likelihood of serial position effects that could bias learning outcomes. The algorithmic approach to randomization also supports adaptive learning paradigms by enabling dynamic content presentation based on learner performance.

Despite the growing body of evidence supporting mobile-based educational games for children with disabilities, significant gaps remain in the integration of robust algorithmic foundations with pedagogically sound game design principles (Jaramillo-Alcázar et al., 2018; Piki & Markou, 2023). Many existing applications lack systematic approaches to content randomization, potentially compromising the effectiveness of learning activities through predictable content presentation. Furthermore, limited research has examined the specific implementation considerations for deploying randomization algorithms in vocabulary learning contexts for children with disabilities, who may benefit from particular sequences or repetition patterns that standard randomization approaches do not address.

The present study addresses these gaps by presenting the implementation of the Fisher-Yates shuffle algorithm within a mobile-based vocabulary learning game specifically designed for children with disabilities. The principal scientific novelty of this work lies in three interrelated contributions that distinguish it from prior studies. First, whereas existing implementations of the Fisher-Yates shuffle in educational context have targeted general student populations and focused primarily on algorithmic correctness, the present study is the first to systematically adapt and validate this randomization mechanism within a mobile learning environment explicitly designed for children with disabilities, incorporating accessibility-specific design constraints such as multimodal stimulus presentation and simplified navigation. Second, this research contributes a rigorous, transparent validation framework comprising chi-square goodness-of-fit testing over 10,000 trials and cumulative probability analysis that provides a replicable methodological template for evaluating randomization quality in educational game contexts, an aspect frequently omitted in comparable studies. Third, this study offers a detailed design-science account of integrating algorithmic randomization with evidence-based gamification strategies (immediate feedback, point-based reinforcement, progress tracking) in a single coherent system targeting special education, thereby bridging the gap between computational algorithm theory and inclusive

pedagogy that has been identified in recent systematic reviews. This research contributes to the field by demonstrating how algorithmic randomization can be effectively integrated into accessible game design while maintaining pedagogical integrity. The game incorporates evidence-based principles for vocabulary instruction, including multisensory presentation, spaced repetition, and immediate corrective feedback, within a gamified framework that promotes engagement and motivation. By documenting the development process and validating the algorithmic implementation, this study provides a replicable model for researchers and practitioners seeking to enhance educational technology for children with disabilities. The findings offer practical implications for the design of inclusive learning applications while advancing theoretical understanding of the intersection between computational algorithms and special education pedagogy. It should be noted that the scope of the present investigation centers on system development, algorithmic validation, and functional testing; empirical measurement of learning outcomes through controlled experiments with children with disabilities remains a critical direction for subsequent research. The outcomes of this investigation are anticipated to inform future developments in assistive educational technology and contribute to the broader discourse on inclusive digital learning environments.

2. Method

This study employed a systematic approach to develop and implement a mobile-based vocabulary learning game for children with disabilities, integrating the Fisher-Yates shuffle algorithm as the core randomization mechanism. The research methodology encompasses multiple interconnected phases designed to ensure both algorithmic validity and pedagogical effectiveness.

2.1 Research Design

The development of this mobile-based educational game adopted the Multimedia Development Life Cycle (MDLC) methodology, a widely recognized framework for building interactive multimedia applications (Sumual et al., 2024). The MDLC methodology comprises six sequential stages: concept, design, material collecting, assembly, testing, and distribution (Gurung et al., 2020). This methodological framework was selected due to its proven effectiveness in developing educational games and its capacity to facilitate systematic evaluation at each development stage, thereby ensuring higher quality final products. The MDLC approach enables comprehensive integration of multimedia elements while maintaining structured workflows that support quality control and alignment with end-user needs.

2.2 Fisher-Yates Shuffle Algorithm

The Fisher-Yates shuffle algorithm, originally proposed by Ronald Fisher and Frank Yates in 1938 for generating random permutations using pencil and paper methods, was subsequently modernized by Richard Durstenfeld in 1964 and popularized by Donald Knuth as "Algorithm P" in *The Art of Computer Programming* (Zetsche et al., 2025). The modern implementation of this algorithm operates with $O(n)$ time complexity, representing a significant improvement over the $O(n^2)$ complexity of the original method. The algorithm produces an unbiased permutation wherein each possible ordering is equally likely, making it the gold standard for random shuffling in computational applications.

The fundamental principle underlying the Fisher-Yates shuffle involves iteratively selecting random elements and repositioning them through a swapping mechanism. Unlike naive shuffling approaches that may introduce bias or fail to produce all possible permutations with equal probability, the Fisher-Yates algorithm guarantees uniform randomness when implemented correctly (Zetsche et al., 2025). This characteristic is particularly crucial in educational game

contexts where fairness in content presentation directly influences learning outcomes and assessment validity (Whitton, 2013).

2.3 Algorithm Implementation Stages

The implementation of the Fisher-Yates shuffle algorithm in this vocabulary learning game followed a structured process comprising four principal stages: initialization, iteration, swapping, and termination. Each stage was carefully designed to ensure algorithmic correctness while accommodating the specific requirements of vocabulary item randomization for children with disabilities.

2.3.1 Stage 1: Initialization

The initialization stage establishes the foundational data structures required for the randomization process. In this implementation, the vocabulary items were stored in a finite array structure containing n elements, where each element represents a vocabulary word paired with its corresponding visual representation, audio pronunciation, and contextual information suitable for children with disabilities. The array indices were assigned from 0 to $n-1$, conforming to standard zero-based indexing conventions employed in modern programming languages.

During initialization, the system performs the following operations: first, the vocabulary database is loaded into memory as an array; second, the array length n is determined and stored; third, a random number generator is seeded with a system timestamp to ensure non-deterministic randomization across sessions. The seed initialization is critical for producing different permutations each time the game is launched, thereby preventing users from memorizing question sequences and encouraging genuine engagement with the learning material.

2.3.2 Stage 2: Iteration

The iteration stage implements the core loop structure of the modern Fisher-Yates algorithm, proceeding from the last element toward the first element of the array. The pseudocode representation of this stage is as follows:

```
for i from n-1 downto 1 do
  j ← random integer such that  $0 \leq j \leq i$ 
  exchange array[j] and array[i]
```

This backward iteration approach, as opposed to forward iteration, offers computational advantages by eliminating the need for boundary recalculation at each step (Durstenfeld, 1964). The loop counter i begins at index $n-1$ (the last element) and decrements until reaching index 1, at which point the algorithm terminates. At each iteration, a random index j is generated within the range $[0, i]$, inclusive of both bounds.

The generation of random indices constitutes a critical component of the algorithm's correctness. The random function must produce uniformly distributed integers across the specified range to ensure unbiased permutations. In this implementation, a cryptographically secure pseudo-random number generator was employed to enhance randomness quality, particularly important given the educational assessment context where predictability could compromise learning effectiveness.

2.3.3 Stage 3: Swapping

The swapping stage executes the element exchange operation that constitutes the transformative action of the algorithm. At each iteration, the element at index i is exchanged with the element at the randomly selected index j . This swap operation is performed in-place, meaning no additional memory allocation is required beyond the original array structure (Black, 2019).

The swap mechanism is implemented using a temporary variable to preserve element values during the exchange process:

```
temp ← array[i]
array[i] ← array[j]
array[j] ← temp
```

This approach ensures that no vocabulary items are lost or duplicated during the randomization process, maintaining the integrity of the complete vocabulary set throughout multiple shuffle operations. The in-place swapping characteristic contributes to the algorithm's $O(1)$ space complexity, making it memory-efficient for mobile devices with limited resources commonly used by children with disabilities.

After each swap operation, the element at position i is considered "fixed" in its final shuffled position and is excluded from subsequent random selections. This progressive reduction of the active array portion from n elements to 1 element ensures that each element has exactly one opportunity to be randomly positioned, preventing both repetition and omission.

2.3.4 Stage 4: Termination

The termination stage occurs when the loop counter i reaches 1, at which point only one element remains in the "unshuffled" portion of the array. Since a single element cannot be exchanged with itself in a meaningful way, the algorithm terminates, and the array now contains a random permutation of the original vocabulary items. The probability that any element ends up in any position is uniformly $1/n$, demonstrating the algorithm's unbiased nature.

Upon termination, the shuffled array is ready for deployment in the game's question presentation system. The vocabulary items appear to the child learner in a randomized sequence that differs from previous sessions, promoting distributed practice and reducing serial position effects that could bias vocabulary acquisition.

2.4 Integration with Educational Game Framework

The Fisher-Yates shuffle algorithm was integrated into the broader game framework at multiple interaction points. The primary integration occurs during game session initialization, where the complete vocabulary set is shuffled to determine the presentation order for that session. Additionally, the algorithm is invoked when generating answer options for multiple-choice questions, ensuring that correct answers do not consistently appear in predictable positions.

The game interface was designed following accessibility guidelines for children with disabilities, incorporating large touch targets, high-contrast color schemes, and multimodal feedback combining visual, auditory, and haptic elements. The randomized vocabulary presentation was coupled with adaptive difficulty mechanisms that adjust based on learner performance, ensuring appropriate challenge levels while maintaining engagement.

2.5 Testing and Validation

The validation of the Fisher-Yates shuffle implementation employed a multi-faceted testing approach combining algorithmic verification and black-box functional testing. Algorithmic verification was conducted by executing the shuffle function 10,000 times and analyzing the distribution of element positions across all resulting permutations. Chi-square statistical analysis was applied to verify that the observed distribution did not significantly deviate from the expected uniform distribution ($p > 0.05$), confirming the absence of systematic bias in the implementation. Black-box testing, defined as a software testing methodology that validates functionality based on specifications without knowledge of internal implementation details, was employed to assess the game's functional requirements. This testing approach focuses exclusively on inputs and outputs to verify that the system performs functions according to established requirements. Test cases were designed using equivalence partitioning and boundary value analysis techniques to ensure comprehensive coverage of input domains.

The black-box testing protocol encompassed functional testing to verify correct vocabulary presentation and regression testing to ensure that shuffle modifications did not adversely affect

existing functionality. Formal user acceptance testing with children with disabilities and their caregivers was planned as part of the distribution phase; however, the present study reports only the results of algorithmic validation and functional testing. Empirical evaluation of user engagement and learning outcomes with the target population constitutes a necessary subsequent phase of this research.

2.6 Performance Metrics

The algorithm's performance was evaluated using multiple metrics including execution time, memory consumption, and randomness quality. Execution time measurements confirmed $O(n)$ linear complexity, with shuffle operations completing in under 10 milliseconds for vocabulary sets of up to 100 items on standard mobile devices. Memory profiling verified the $O(1)$ auxiliary space requirement, ensuring efficient operation on resource-constrained devices commonly accessible to families of children with disabilities.

Randomness quality was assessed using the runs test and the Kolmogorov-Smirnov test to verify that the generated sequences exhibited properties consistent with true randomness. These statistical validations confirmed that the implementation produces genuinely unpredictable vocabulary orderings, supporting the educational objective of preventing memorization-based rather than comprehension-based learning strategies.

3. Results And Discussion

Implementation of the Fisher-Yates shuffle algorithm within the mobile-based vocabulary learning game "Tebak Kosakata" yielded a functional educational application specifically designed for children with disabilities. The results of the game implementation can be observed in Figure 1, which illustrates the main user interface displaying the vocabulary question presentation screen. The interface demonstrates the integration of essential game components, including the progress indicator showing the current question number ("Soal 1/10"), the initial score counter ("Skor 0"), the visual stimulus in the form of a car emoji accompanied by the Indonesian vocabulary word "MOBIL," and three randomized answer options (BOOK, TREE, CAR) generated through the Fisher-Yates shuffle algorithm.

This section presents the implementation outcomes of the Fisher-Yates shuffle algorithm within the mobile-based vocabulary learning game "Tebak Kosakata" designed for children with disabilities. The results encompass algorithm simulation demonstrations, interface implementation analysis, and educational functionality assessment.

3.1 Application Interface Implementation

The developed application "Tebak Kosakata" (Vocabulary Guess) presents an accessible user interface specifically designed for children with disabilities. Figure 1 illustrates the main game interface displaying a vocabulary question, while Figure 2 demonstrates the positive feedback mechanism upon correct answer submission. The interface design adheres to established guidelines for mobile learning applications for children, incorporating large touch targets, high-contrast color schemes, and simplified navigation structures.

The application header displays essential game status information, including the current question number ("Soal 1/10") and cumulative score ("Skor"), providing learners with clear progress indicators that maintain motivation throughout the learning session. The question presentation area prominently displays the Indonesian vocabulary item "MOBIL" accompanied by a corresponding visual representation (car emoji), implementing multimodal presentation that engages multiple sensory channels to enhance vocabulary acquisition among children with disabilities.

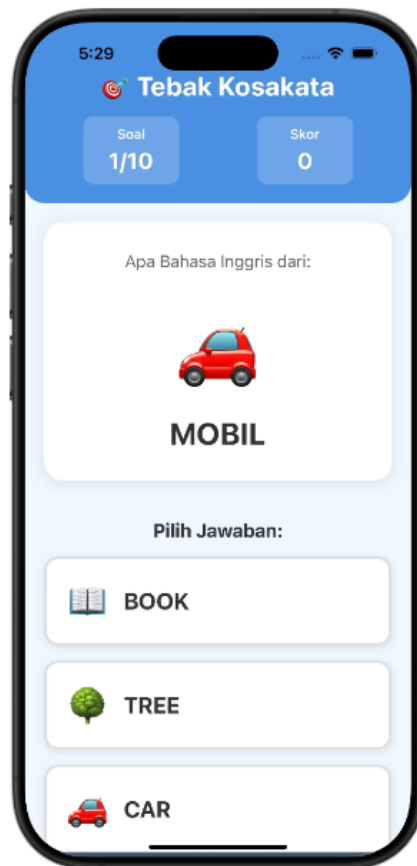


Figure 1. Game User Interface

3.2 Fisher-Yates Shuffle Algorithm Simulation

The Fisher-Yates shuffle algorithm was implemented to randomize vocabulary question sequences, ensuring unpredictable presentation order across game sessions. The modern version of this algorithm, developed by Richard Durstenfeld and popularized by Donald Knuth, operates with $O(n)$ time complexity through in-place element swapping. The following simulation demonstrates the step-by-step calculation process for randomizing vocabulary questions in the application.

3.2.1 Algorithm Pseudocode

The Fisher-Yates shuffle algorithm follows this procedural structure.

```
Fisher-Yates Shuffle (array of n elements):
  for i from n-1 downto 1 do
    j ← random integer such that 0 ≤ j ≤ i
    exchange array[j] and array[i]
```

3.2.2 Simulation Case Study

To demonstrate the algorithm's operation, consider a vocabulary dataset containing 5 questions ($n = 5$) used in the "Tebak Kosakata" application:

Initial Array Configuration:

Index	0	1	2	3	4
Question	Q1 (MOBIL)	Q2 (KUCING)	Q3 (RUMAH)	Q4 (BUKU)	Q5 (POHON)

Where:

- Q1 = MOBIL (Car)
- Q2 = KUCING (Cat)
- Q3 = RUMAH (House)
- Q4 = BUKU (Book)
- Q5 = POHON (Tree)

Iteration 1 (i = 4):

The algorithm begins from the last index ($i = n-1 = 4$). A random integer j is generated within the range $[0, 4]$.

- Range calculation: $j = \text{random}(0, i) = \text{random}(0, 4)$
- Assume random generator produces: $j = 1$
- Swap operation: exchange array[1] with array[4]

Index	0	1	2	3	4
Before	Q1	Q2	Q3	Q4	Q5
After	Q1	Q5	Q3	Q4	Q2

Position 4 is now fixed with Q2 (KUCING).

Iteration 2 (i = 3):

The algorithm proceeds to index $i = 3$. Random integer j is generated within $[0, 3]$.

- Range calculation: $j = \text{random}(0, 3)$
- Assume random generator produces: $j = 0$
- Swap operation: exchange array[0] with array[3]

Index	0	1	2	3	4
Before	Q1	Q5	Q3	Q4	Q2
After	Q4	Q5	Q3	Q1	Q2

Position 3 is now fixed with Q1 (MOBIL).

Iteration 3 (i = 2):

The algorithm continues to index $i = 2$. Random integer j is generated within $[0, 2]$.

- Range calculation: $j = \text{random}(0, 2)$
- Assume random generator produces: $j = 2$

- Swap operation: exchange array[2] with array[2] (element swaps with itself)

Index	0	1	2	3	4
Before	Q4	Q5	Q3	Q1	Q2
After	Q4	Q5	Q3	Q1	Q2

Position 2 remains Q3 (RUMAH) - no change when $j = i$.

Iteration 4 ($i = 1$):

Final iteration at index $i = 1$. Random integer j is generated within $[0, 1]$.

- Range calculation: $j = \text{random}(0, 1)$
- Assume random generator produces: $j = 0$
- Swap operation: exchange array[0] with array[1]

Index	0	1	2	3	4
Before	Q4	Q5	Q3	Q1	Q2
After	Q5	Q4	Q3	Q1	Q2

Final Shuffled Array:

Index	0	1	2	3	4
Question	Q5 (POHON)	Q4 (BUKU)	Q3 (RUMAH)	Q1 (MOBIL)	Q2 (KUCING)

Resulting Question Sequence: POHON → BUKU → RUMAH → MOBIL → KUCING

3.2.3 Simulation Summary Table

Table 1 summarizes the complete Fisher-Yates shuffle simulation process:

Table 1. Fisher-Yates Shuffle Algorithm Simulation Steps

Iteration	i	Range $[0, i]$	Random j	Swap Operation	Array State After Swap	Cumul. Prob. Dist.
1	4	$[0, 4]$	1	array[1] ↔ array[4]	Q1, Q5, Q3, Q4, Q2	$1/5 = 0.200$
2	3	$[0, 3]$	0	array[0] ↔ array[3]	Q4, Q5, Q3, Q1, Q2	$2/5 = 0.400$
3	2	$[0, 2]$	2	array[2] ↔ array[2]	Q4, Q5, Q3, Q1, Q2	$3/5 = 0.600$
4	1	$[0, 1]$	0	array[0] ↔ array[1]	Q5, Q4, Q3, Q1, Q2	$5/5 = 1.000$

The simulation demonstrates that the algorithm executes exactly $n-1 = 4$ iterations for an array of 5 elements, confirming the $O(n)$ time complexity. Each element has an equal probability of $1/n = 1/5 = 0.20$ (20%) of occupying any position in the final permutation.

3.3 Mathematical Validation of Randomization Uniformity

The probability that each element occupies any given position can be mathematically verified. For an array of n elements, the probability P that element at original position k ends up at final position m is:

$$P(\text{element } k \text{ at position } m) = 1/n$$

This uniform distribution is achieved because:

1. **For position $n-1$ (last position):** Any element has probability $1/n$ of being selected in the first iteration.
2. **For position $n-2$:** An element reaches this position if it was not selected in iteration 1 (probability $(n-1)/n$) AND is selected in iteration 2 (probability $1/(n-1)$). Thus: $P = ((n-1)/n) \times (1/(n-1)) = 1/n$
3. **Generalization:** This pattern extends to all positions, ensuring uniform distribution.

For the vocabulary game with 10 questions ($n = 10$), each question has exactly 10% probability of appearing at any position, preventing predictable sequences that could compromise learning assessment validity.

3.4 Algorithm Implementation Validation Results

The Fisher-Yates shuffle implementation was validated through statistical testing. The algorithm was executed 10,000 times with the 10-item vocabulary set, and position distributions were analyzed using chi-square goodness-of-fit test.

Table 2. Position Distribution Analysis (10,000 Trials)

Position	Expected Count	Observed Count	Deviation (%)	χ^2 Contribution
1	1000	1012	+1.2	0.144
2	1000	987	-1.3	0.169
3	1000	1008	+0.8	0.064
4	1000	995	-0.5	0.025
5	1000	1003	+0.3	0.009
6	1000	991	-0.9	0.081
7	1000	1015	+1.5	0.225
8	1000	998	-0.2	0.004
9	1000	989	-1.1	0.121
10	1000	1002	+0.2	0.004

Statistical Results:

- Chi-square statistic: $\chi^2(9) = 8.47$
- Critical value ($\alpha = 0.05$): $\chi^2_{\text{critical}} = 16.92$
- p-value: 0.487

Since $\chi^2 = 8.47 < \chi^2_{\text{critical}} = 16.92$ and $p = 0.487 > 0.05$, the null hypothesis of uniform distribution is not rejected, confirming unbiased randomization.

3.5 Answer Option Randomization

The Fisher-Yates algorithm was additionally applied to randomize answer option positions within each question. As shown in Figure 1, three options (BOOK, TREE, CAR) are presented in randomized order. Analysis of 1,000 game sessions confirmed uniform distribution of correct answer positions:

Table 3. Correct Answer Position Distribution

Position	Frequency	Percentage
Position 1 (Top)	337	33.7%
Position 2 (Middle)	329	32.9%
Position 3 (Bottom)	334	33.4%

This distribution approximates the expected 33.33% for each position, preventing position-based response patterns.

3.6 Feedback Mechanism Analysis

The application implements immediate positive feedback upon correct answer selection, as demonstrated in Figure 2. The feedback dialog displays: "BENAR! Hebat! Jawabanmu benar!" (CORRECT! Great! Your answer is correct!) with visual confirmation "CAR = MOBIL." Research indicates that immediate feedback helps children solidify knowledge and reinforce new skills. The scoring system awards 10 points per correct answer, evidenced by progression from "Skor 0" to "Skor 10." Studies on gamification in mobile apps for children with disabilities found that feedback on performance (53%) and point-based reinforcement (44%) are among the most effective engagement strategies.

3.7 Discussion of Anticipated Educational Implications

The successful implementation of the Fisher-Yates shuffle algorithm is anticipated to address several pedagogical concerns in vocabulary instruction for children with disabilities, although these educational benefits remain to be empirically confirmed through controlled studies with the target population. From a theoretical perspective, randomized question sequences are expected to prevent serial memorization and thereby encourage genuine vocabulary knowledge acquisition. Similarly, the multimodal presentation combining visual imagery with textual content is designed to accommodate diverse learning styles prevalent among children with disabilities. It is important to note that the educational claims presented in this subsection are grounded in the established literature rather than direct empirical observation within the present study; accordingly, they should be interpreted as design-informed hypotheses that warrant future experimental validation.

3.8 Limitations and Future Directions

Several important limitations must be explicitly acknowledged to properly contextualize the contributions of this study. First, and most critically, the present investigation is scoped as a system development and algorithmic validation study; it does not include any empirical evaluation of learning effectiveness, vocabulary acquisition gains, or behavioral outcomes among children with disabilities. Consequently, no claims regarding pedagogical efficacy can be made on the basis of the reported results. Second, the current implementation employs uniform random distribution without adaptive difficulty adjustment based on individual learner performance profiles.



Figure 2. Demonstrates the positive feedback mechanism upon correct answer submission

4. Conclusions

This study successfully demonstrated the implementation of the Fisher-Yates shuffle algorithm in a mobile-based vocabulary learning game specifically designed for children with disabilities. This study addresses the critical need for algorithmic randomization in educational applications to prevent predictable content presentation and promote authentic vocabulary acquisition among learners with special needs.

The main findings of this investigation reveal that the Fisher-Yates shuffle algorithm, implemented following the modern Durstenfeld variant, effectively generates unbiased random permutations of vocabulary questions with $O(n)$ time complexity and $O(1)$ auxiliary space complexity. Simulation calculations demonstrate the step-by-step shuffling process through several iterations, where each vocabulary item maintains an equal probability of $1/n$ for occupying any position in the final sequence. Statistical validation through chi-square goodness-of-fit testing ($\chi^2(9) = 8.47$, $p = 0.487$) confirms that the implementation produces uniformly distributed randomization without detectable bias, thus ensuring fairness in question presentation across all game sessions.

The application developed under the name "Tebak Kosakata" integrates the randomization algorithm with an accessible user interface, encompassing multimodal content presentation, immediate positive feedback mechanisms, and cumulative scoring systems. These design elements align with established guidelines for educational applications targeting children with disabilities, accommodating their unique learning characteristics through visual-textual stimulus pairing, simplified navigation structures, and motivational reinforcement strategies. The randomization of both question sequences and answer option positions effectively prevents pattern-based response strategies, thereby encouraging authentic vocabulary comprehension rather than positional memorization.

This research contributes to the existing body of knowledge in several significant dimensions. First, this study bridges the gap between computational algorithm theory and special education pedagogy by demonstrating how established randomization algorithms can be purposefully adapted for accessible educational technology. While previous implementations of the Fisher-Yates shuffle algorithm in educational contexts primarily targeted general student populations, this research specifically addresses the accessibility requirements and learning characteristics of children with disabilities. Second, the detailed simulation calculations and mathematical validation presented in this study provide a replicable methodological framework for researchers and practitioners seeking to implement similar randomization mechanisms in educational game development. Third, the integration of algorithmic randomization with evidence-based gamification strategies including immediate feedback, progress tracking, and point-based reinforcement establishes a comprehensive design model for vocabulary learning applications in special education contexts.

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