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Neutrosophic Causal Analysis of Gamification Strategies for Promoting Reading Habits in Eighth-Grade Students

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Abstract. This study explores the connection between gamification elements and the development of reading habits among eighth-grade students through neutrosophic set theory and fuzzy-set qualitative comparative analysis (fsQCA). This investigation is different from previous ones because most studies focused on gamification fail to embrace the uncertainty and complexity of real life when it comes to generalizability. As a result, a neutrosophic framework was established for this study. To this end, 15 individuals answered a neutrosophic Likert scale questionnaire which resulted in a conglomerate of ratings that depicts their opinion on the gamified elements, technology use, and feedback loop systems afforded to them in the experience. Through fuzzifying the results, it became clear that one of the strongly relevant adjustments was that technology use and feedback loops generated more motivation to read than gaming elements alone. Ultimately, the pathways to developing reading habits exist in a conjunctural and equifinal manner no one has applied neutrosophic logic to the field of education with results that teachers can use to determine the best way to configure gamified reading experiences. Technology should be used as well as acknowledged and learners need to be flexible creatures on which design decisions are based to create a gamified experience that fosters adolescent reading habits.

Keywords: Gamification, Reading Habit, Neutrosophic Set Theory, fsQCA, Educational Motivation

1. Introduction

This study investigates the relationship between gamification [1] and the development of reading habits among eighth-grade students—an increasingly relevant topic in contemporary education. In an era filled with digital stimuli and fast-paced interactions, fostering a lasting appreciation for reading has become a formidable challenge. This research applies neutrosophic set theory, a logic-based framework that models degrees of truth (T), indeterminacy (I), and falsity (F), to assess the complex and uncertain relationships between gamification strategies and students' reading behaviors [2,3].

The justification stems from the disparity between students wanting to learn—many want to learn via active digital experiences—and reading as a somewhat passive experience. Therefore, while many results champion the reading of books—from in-school initiatives to the creation of digital libraries (school and at-home) to champion access—few take complicated and contradictory perspectives from students into account through the prisms of contradiction. In addition, the findings of books and gaming do not necessarily take a focused assessment of need, but instead a grand theory of everything, where mere alignments of successes or failures are not attributed according to engagement findings [4].

Thus, to address this gap, this study aims to use the analytical approach stemming from neutrosophic fuzzy-set Qualitative Comparative Analysis (fsQCA) based upon causal complexity theory, educational gamification engagement, and neutrosophic logic[5,6]. This study will review the literature supporting the theory of causation and causality from causal theories, supported by neutrosophy and gamification, then present the approach and research design involving neutrosophic Likert scales for data collection, fuzzification, and application of fsQCA. Findings will be reported through causal configurations, followed by discussion, conclusion, and recommendations for future study.

2. Preliminaries

2.1. Complexity Theory, Causality, and Neutrosophic Sets in Education

In educational contexts, connections between variables rarely manifest as linear or self-evident. Rather, as complexity theory suggests—particularly through Edgar Morin's paradigm of complex thought [7]—causal relationships interweave in intricate patterns where identical starting points may yield diverse outcomes depending on the learning environment's dynamics. This theoretical framework emphasizes three key principles: conjunction, equifinality, and causal asymmetry [8, 9].

Conjunction demonstrates that multiple factors must align synergistically to generate outcomes—for instance, student motivation (M), appropriate pedagogical methods (P), and institutional support (I) can be represented as:

$$E = f(M \cap P \cap I) \quad (1)$$

where E denotes educational effectiveness.

Equifinality[10,11] indicates that identical educational achievements, such as critical thinking development (CT), can be attained through different pathways, expressible as:

$$CT = \{p_1 \vee p_2 \vee p_3 \vee \ldots \vee p_n\} \quad (2)$$

where each p_i represents a distinct pedagogical approach.

Causal asymmetry[10,11] warns that while certain conditions may facilitate learning (like a highly qualified teacher, T), their absence doesn't necessarily precipitate academic failure, as other elements may compensate:

$$\neg T \nrightarrow \neg S \quad (3)$$

where S represents student success.

An illustrative example can be observed in a university implementing personalized tutoring programs[12]. For certain students, this intervention is determinative for academic success. For others, flexible scheduling or access to digital learning platforms may be the decisive factor. Even if one factor is removed, outcomes will not be uniformly affected, demonstrating that the relationship between pedagogical strategies and results is not direct or universal, but rather complex, contextual, and sensitive to multiple combinations.

This is where neutrosophy offers an expanded perspective: by incorporating degrees of truth (T), falsity (F), and indeterminacy (I), neutrosophic sets can be formalized as[13]:

$$A = \{x(T\_A(x), I\_A(x), F\_A(x)) \mid x \in X\} \quad (4)$$

Enabling representation of the uncertainty and ambiguity inherent in actual educational processes. Thus, this logic provides a framework more aligned with the human and dynamic nature of education, acknowledging that between pedagogical intention and obtained results exist gray zones requiring modeling with epistemological sensitivity . As Morin articulated in his principle of recursive causality[14], educational outcomes simultaneously act as causes and products of the process that generates them, creating self-reinforcing feedback loops that neutrosophic logic is uniquely positioned to capture.

2.2. Neutrosophic Liker scales

Surveys using neutrosophic Likert scales [15,16] effectively measure the diversity of opinions and their influence on public policy and social discourse, capturing areas of consensus, disagreement, and ambivalence.

Below we present the fundamental definitions and concepts related to neutrosophic sets and single-valued neutrosophic sets.

Definition 1 ([17]). Let U be a discursive universe. $N = \{(x , T (x), I (x), F (x)): x \in U \}$ is a neutrosophic set, denoted by a truth membership function, $TN : U \rightarrow]0^-, 1^+[$; an indeterminate membership function , $IN : U \rightarrow]0^-, 1^+[$; and a falsehood membership function , $FN : U \rightarrow]0^-, 1^+[$.

Single-valued neutrosophic sets provide a way to represent and analyze possible elements in the universe of discourse U

Definition 2 ([18]). Let U be a discursive universe. A single-valued neutrosophic set is defined as $N = \{(x , T (x), I (x), F (x)): x \in U \}$, which is identified by a truth membership function, $TN : U \rightarrow [0, 1]$; indeterminacy membership function , $IN : U \rightarrow [0, 1]$; and falsehood membership function , $FN : U \rightarrow [0, 1]$, with $0 \leq TN (x)+ IN (x)+ FN (x)\leq 3$

Using neutrosophic scales with single-valued neutrosophic sets, responses are categorized according to the total of the True, Indeterminate, and False components as follows [19]:

- T+I+F<1: Incomplete
- T+I+F=1: Complete
- T+I+F>1: Contradictory

These values are obtained because, in many cases, opinions are incomplete or contradictory. This classification is one of the advantages of using neutrosophic methods, as it allows for a more nuanced understanding of the different degrees of truth, indeterminacy, and falsity in the responses [20-23].

2.3. Gamification: The Necessity of Causal Understanding

Gamification has emerged as an innovative strategy incorporating game elements into non-game environments such as education, work, and healthcare. This approach aims to capture participants' attention, encouraging engagement through rewards, challenges, and interactive dynamics. In educational contexts, gamification transforms routine activities into engaging experiences intended to motivate deeper student involvement [24]. However, despite its growing popularity, a critical gap exists in understanding the causal mechanisms that make certain gamification strategies effective while others fail [25].

Current gamification practices frequently employ elements such as points, badges, leaderboards, and narratives [26] based on general assumptions about motivation rather than empirically validated causal relationships. While these elements derive from game design principles, their application in educational contexts demands a more nuanced understanding of how, why, and under what conditions influence learning behaviors. The prevalent approach of implementing multiple gamification elements simultaneously without considering their complex interactions represents a significant limitation in current practice.

From a theoretical perspective, the effectiveness of gamification has been linked to psychological frameworks such as self-determination theory, which emphasizes the importance of autonomy, competence, and relatedness in human motivation [27]. By offering users control over their decisions and opportunities to demonstrate mastery, gamified dynamics can strengthen engagement. However, the precise causal pathways through which these psychological needs are satisfied by specific game elements remain insufficiently understood, leading to inconsistent implementation outcomes.

The complexity of causal relationships in educational gamification becomes particularly evident when examining the varied results across different studies. For instance, while some research demonstrates that students exposed to points and challenge systems read more books on their own initiative [28], other implementations show minimal or even negative effects.[29] These inconsistencies suggest that gamification effectiveness likely depends on specific causal combinations and contextual factors rather than the mere presence of game elements.

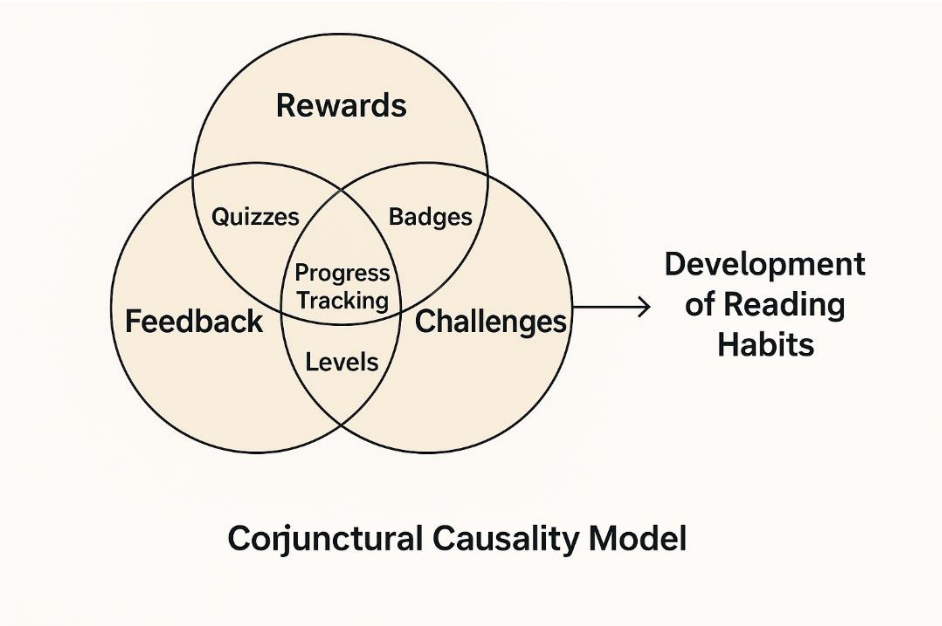

Figure 1. Conjunctural Causality in Educational Gamification: A Venn-Pathway Model of Alternative Routes Toward Reading Habit Formation.

This diagram illustrates the principle of equifinality in educational gamification, showing how different combinations of game elements—such as challenges, narrative immersion, rewards, peer feedback, and customization—can lead to the same outcome: the development of sustained reading habits. The figure highlights that no single gamification element is universally effective on its own; rather, specific pathways composed of conjunctural configurations are what generate success. This model underscores the need for causal-comparative methods to identify robust combinations across contexts.

Failed gamification initiatives provide further evidence of the necessity for causal understanding. Studies have demonstrated that improper implementation can generate disinterest or rejection when participants perceive mechanics as artificial or manipulative [30]. These failures typically stem from a fundamental misunderstanding of the causal relationships between intervention components and desired outcomes. Without a clear causal model, gamification risks being reduced to "superficial reinforcement" that fails to generate sustainable behavioral changes.

The technological dimension adds another layer of complexity to understanding gamification's causal mechanisms. Mobile apps and online platforms have facilitated the creation of accessible and personalized gamified experiences, yet this technological dependence could limit reach in communities with limited access to devices or internet connectivity [31]. This raises important questions about how technological factors interact with gamification elements to influence outcomes across different populations and settings.

Future gamification research must prioritize the identification of causal patterns through methodologies capable of handling complexity and uncertainty. Advanced analytical approaches like fuzzy-set qualitative comparative analysis (fsQCA) and neutrosophic logic offer promising avenues for untangling the complex causal conditions under which gamification elements effectively influence educational outcomes. These methodologies can accommodate the equifinality (multiple pathways to the same outcome) and conjunctural causation (combinations of conditions rather than isolated factors) that characterize educational processes.

In conclusion, while gamification presents significant opportunities for transforming educational engagement, advancing the field requires a fundamental shift toward causally informed design. By moving beyond simplistic implementation of game elements to a deeper understanding of causal mechanisms, researchers and educators can develop more effective, targeted interventions that produce sustainable improvements in learning behaviors and outcomes. This shift from intuition-based to evidence-based causal design represents the next critical frontier in educational gamification research...

3. Material and Methods

3.1 Research Design

This investigation implements a neutrosophic fuzzy-set qualitative comparative analysis (fsQCA) to examine the relationship between gamification strategies and reading habits among eighth-grade students. The methodology follows a systematic process that accounts for uncertainty, indeterminacy, and complexity in educational phenomena.

3.2 Problem Identification and Variable Selection

The defined outcome is Reading Habit (RH) among eighth-grade students. Three key predictor variables were identified:

- Implemented Game Elements (IGE): Incorporation of elements such as points, badges, leaderboards, and challenges into reading activities.
- Applied Digital Technology (ADT): Use of applications, digital platforms, and electronic devices facilitating gamified reading experiences.
- Immediate Feedback (IF): Systems providing immediate responses and rewards for participation in gamified reading activities.

3.3 Data Collection

A survey was conducted among 15 eighth-grade students from an Ecuadorian school who participated in a reading promotion program with gamification elements during one academic semester. Responses were collected using neutrosophic Likert scales, where each response is expressed as a triplet (T, I, F):

T: degree of truth (positive membership)

I: degree of indeterminacy (neutral membership)

F: degree of falsity (negative membership)

This approach captures nuances in participant responses beyond traditional Likert scales, allowing for expression of partial truth, uncertainty, and falsity simultaneously.

3.4 Fuzzification Process

The neutrosophic sets obtained through surveys were transformed into equivalent fuzzy sets using Equation 1[6]:

$$\mu A(x) = 1 - \frac{1}{2}[(1 - T_A(x)) + \max\{I_A(x), F_A(x)\}] \quad (5)$$

where:

$\mu A(x)$ is the equivalent fuzzy membership function
$T_A(x)$ is the truth-membership function
$I_A(x)$ is the indeterminacy-membership function
$F_A(x)$ is the falsity-membership function

This transformation maintains the inherent complexity of the original neutrosophic data while enabling subsequent analyses within the fuzzy-set framework.

3.5 Analysis Procedure

Fuzzy-set Qualitative Comparative Analysis (fsQCA) was implemented to identify combinations of factors associated with reading habit development. The analysis evaluated both individual conditions and their various configurations using two key metrics:

3.5.1 Consistency Analysis [32]

Consistency measures how reliably a set of conditions produces the desired outcome, calculated using Equation 2:

$$Consistency\ (Y_i \leq X_i) = \frac{\sum \min (X_i, Y_i)}{\sum Y_i} \quad (6)$$

3.5.2 Coverage Analysis

Coverage indicates the degree to which the outcome is explained by an arrangement of conditions, calculated using Equation 3:

$$Coverage\ (Y_i \leq X_i) = \frac{\sum \min (X_i, Y_i)}{\sum X_i} \quad (7)$$

Where:

$X_i$is the membership value of case i in the set of causal conditions.
$Y_i$is the membership value of case iii in the result set.

Generally, consistency and coverage values above 0.8 indicate strong relationships between conditions and outcomes. These metrics enable rigorous assessment of both necessary and sufficient conditions for developing reading habits through gamified interventions.

3.6 Software Implementation

Data processing was performed using fsQCA for Windows software, which facilitates set-theoretic analysis and identification of complex causal relationships. The software enables systematic evaluation of necessary conditions, sufficient conditions, and multiple combinatorial pathways leading to the outcome of interest.[33]

4. Results.
4.1 Neutrosophic Survey Data

A survey was conducted among 15 eighth-grade students using neutrosophic Likert scales to measure how different gamification strategies influence reading habits. Table 1 presents the raw neutrosophic data collected, where each value is expressed as a triplet (T, I, F) representing truth, indeterminacy, and falsity degrees.

Table 1. Survey data

Student	Implemented Game Elements (IGE)	Applied Digital Technology (ADT)	Immediate Feedback (IF)	Reading Habit (RH)
1	(0.9, 0.8, 0.1)	(0.6, 1.0, 0.6)	(0.3, 0.7, 0.3)	(0.8, 0.6, 0.7)
2	(0.6, 0.6, 0.6)	(1.0, 1.0, 1.0)	(0.6, 0.1, 0.6)	(0.6, 0.6, 0.7)
3	(0.8, 0.7, 0.4)	(0.7, 0.9, 0.6)	(0.8, 0.6, 0.6)	(0.8, 0.6, 0.6)
4	(1.0, 1.0, 0.0)	(0.8, 0.8, 0.0)	(1.0, 0.9, 0.3)	(0.7, 1.0, 0.9)

Student	Implemented Game Elements (IGE)	Applied Digital Technology (ADT)	Immediate Feedback (IF)	Reading Habit (RH)
5	(1.0, 0.6, 0.0)	(1.0, 0.6, 1.0)	(1.0, 0.6, 1.0)	(0.9, 0.6, 0.1)
6	(0.9, 0.9, 0.9)	(0.9, 0.9, 0.9)	(0.9, 0.9, 0.9)	(0.9, 0.9, 0.9)
7	(0.1, 0.6, 0.8)	(1.0, 0.0, 0.0)	(0.6, 0.6, 0.6)	(0.8, 0.6, 0.1)
8	(1.0, 0.9, 0.1)	(0.9, 0.9, 0.1)	(0.9, 0.9, 0.1)	(0.9, 0.9, 0.1)
9	(1.0, 1.0, 0.0)	(0.8, 0.8, 0.0)	(1.0, 0.0, 0.0)	(0.9, 0.0, 0.0)
10	(0.7, 1.0, 0.1)	(0.9, 0.4, 0.0)	(0.6, 0.9, 0.1)	(1.0, 0.0, 0.0)
11	(0.4, 0.7, 0.1)	(0.3, 0.9, 0.4)	(0.8, 0.4, 0.6)	(0.4, 0.8, 0.3)
12	(0.6, 1.0, 0.6)	(0.6, 0.6, 0.1)	(0.1, 0.6, 0.7)	(1.0, 0.0, 0.1)
13	(0.8, 0.6, 0.3)	(0.7, 0.7, 0.3)	(0.9, 0.5, 0.2)	(0.8, 0.5, 0.3)
14	(0.9, 0.3, 0.2)	(0.8, 0.7, 0.1)	(0.7, 0.6, 0.4)	(0.7, 0.6, 0.3)
15	(0.7, 0.5, 0.4)	(0.9, 0.4, 0.2)	(0.8, 0.3, 0.1)	(0.9, 0.2, 0.1)

4.2 Distribution of Values After Fuzzification

The neutrosophic data collected through the survey were transformed into fuzzy values using Equation 5 Table 2 presents the results of this fuzzification process for each student and variable.

Table 2. Fuzzy values after fuzzification

Student	Implemented Game Elements (IGE)	Applied Digital Technology (ADT)	Immediate Feedback (IF)	Reading Habit (RH)
1	0.45	0.30	0.35	0.45
2	0.40	0.50	0.45	0.40
3	0.45	0.35	0.40	0.45
4	0.50	0.50	0.40	0.35
5	0.60	0.47	0.45	0.60
6	0.50	0.50	0.50	0.50
7	0.15	1.00	0.40	0.55
8	0.50	0.50	0.50	0.50
9	0.50	0.50	1.00	0.95
10	0.35	0.70	0.35	1.00
11	0.30	0.15	0.40	0.25
12	0.30	0.45	0.15	0.95
13	0.45	0.40	0.55	0.50
14	0.65	0.50	0.40	0.45
15	0.45	0.60	0.65	0.80

4.3 Analysis of Necessary Conditions

A necessary condition analysis was performed to determine the consistency and coverage of each variable with respect to reading habit development, using Equations 6 and 7. The results are presented in Table 3.

Table 3. Analysis of necessary conditions

Condition	Consistency	Coverage
IGE	0.5869	0.5985
ADT	0.6875	0.6347
IF	0.6442	0.6786
RH	0.6238	0.5972

The analysis reveals that Applied Digital Technology (ADT) has the highest consistency value (0.6875), followed by Immediate Feedback (IF) at 0.6442. This suggests that the use of digital technologies and immediate feedback systems are key factors in developing reading habits in a gamified context.

In terms of coverage, Immediate Feedback (IF) shows the highest value (0.6786), followed by Applied Digital Technology (ADT) with 0.6347. This indicates that immediate feedback has a greater capacity to cover different cases in which reading habits develop.

Implemented Game Elements (IGE) show the lowest values in both consistency (0.5869) and coverage (0.5985), suggesting that although they are important, they are less determined on their own compared to the other factors.

4.4 Set Matching Analysis

Set matching analysis provides insight into how different conditions interrelate in the context of reading habit development. The results are presented in Table 4.

Table 4. Set matching analysis

Conditions	Coincidence
IGE, ADT, IF	0.3628
IGE, ADT	0.3832
IGE, IF	0.3942
ADT, IF	0.5072

This analysis reveals significant patterns:

- The combination of all three factors (IGE, ADT, IF) shows a correlation coefficient of 0.3628, indicating a moderate-low level of correlation. Although each of these conditions influences reading habits, their combined effect does not maximize their potential in this analysis.
- For the combination of Implemented Game Elements (IGE) and Applied Digital Technology (ADT), the coincidence is 0.3832. This result shows that the interaction between these two conditions produces a moderate effect on reading habits.
- The correlation between Implemented Game Elements (IGE) and Immediate Feedback (IF) is 0.3942, slightly higher than the previous combination. This suggests that game elements, when combined with immediate feedback systems, have a moderate impact on reading habit development.
- The correlation between Applied Digital Technology (ADT) and Immediate Feedback (IF) is 0.5072, the highest value among the combinations evaluated. This indicates that the interaction between these two factors has a stronger correlation and suggests that the use of digital technologies combined with immediate feedback systems has a stronger and more direct relationship with the development of reading habits compared to other combinations.

4.5 Results of Subset/Superset Analysis

Detailed analysis of the subset/superset results reveals significant patterns in the relationship between gamification strategies and reading habits in eighth-grade students, as shown in Table 5.

Table 5. Results of subset/superset analysis

Terms	Consistency	Coverage	Set
IGE, ADT, IF	0.362847	0.388323	0.375585
IGE, ADT	0.383168	0.410749	0.396958
IGE, IF	0.394222	0.422575	0.408399
ADT, IF	0.507186	0.543916	0.525551
IGE	0.586946	0.598515	0.592731
ADT	0.687462	0.634701	0.661081
IF	0.644228	0.678555	0.661391

4.5.1 Individual Conditions Analysis

- Applied Digital Technology (ADT) shows a consistency of 0.687462 and coverage of 0.634701, with a combined average of 0.661081.
- Immediate Feedback (IF) has a consistency of 0.644228 and coverage of 0.678555, with a combined average of 0.661391.
- Implemented Game Elements (IGE) show a consistency of 0.586946 and coverage of 0.598515, with a combined average of 0.592731.

This indicates that both Applied Digital Technology and Immediate Feedback have a similar and significant influence on the development of reading habits, while Implemented Game Elements, although important, have a slightly smaller impact when considered in isolation.

4.5.2 Combination Analysis

- The combination of ADT and IF shows the largest joint effect, with a consistency of 0.507186 and coverage of 0.543916 (combined mean of 0.525551). This suggests that the integration of digital technologies with immediate feedback systems creates a particularly effective environment for developing reading habits.
- Combinations that include all three factors (IGE, ADT, IF) show lower values (consistency: 0.362847, coverage: 0.388323, set: 0.375585), which could indicate that an overly complex approach may dilute the effectiveness of the intervention.

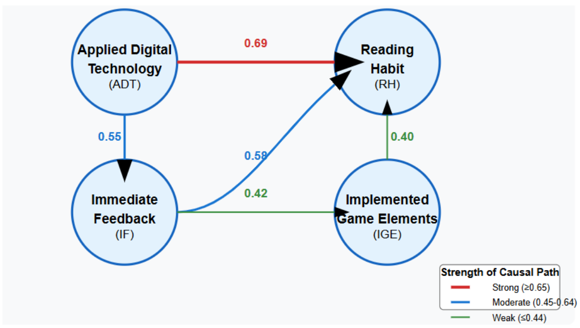

Figure 2. Directed Acyclic Graph (DAG) Representing Causal Relationships Among Gamification Factors and Reading Habit

This graph visually summarizes the strongest causal paths identified through neutrosophic fuzzy-set analysis. The bold arrows highlight the primary pathway from Applied Digital Technology (ADT) directly to Reading Habit (RH), *and through Immediate Feedback (IF), indicating a reinforced mediated effect. Thinner arrows represent weaker, yet present, causal contributions from Implemented Game Elements (IGE).*

5. Discussion

The neutrosophic analysis of gamification strategies and their influence on reading habits among eighth-grade students has yielded several significant insights that have both theoretical and practical implications for educational interventions.

5.1 Synergistic Effects of Digital Technology and Immediate Feedback

The results present a combined correlation of 0.5072 between Applied Digital Technology and Immediate Feedback when both are applied. Such interaction supports twenty-first century learning theories which indicate that rapid suggestions are necessary within digital confines. Therefore, the combination fosters a "reactive digital environment" that seemingly works best at cultivating reading behaviors. This is a natural progression of findings [32] because it indicates that although digital mediums operate alone (consistency: 0.6875), their use is exponentially increased when paired with immediate feedback systems. Therefore, relative to instructional design, it demonstrates that developers of reading applications should focus on design elements of extensive feedback systems instead of the type of content offered or the usability.

5.2 The Paradox of Complexity in Gamification Design

Interestingly, we find a "complexity paradox" regarding gamification design. While each element (IGE, ADT, IF) positively correlates with forming reading habits, the consistency (0.362847) and coverage (0.388323) values are lowest under the condition that all three are introduced simultaneously. One would think that more is better, but in this case, less is more. Yet this paradox is not surprising based on the literature. Cognitive load theory [33] supports the advantages of having less. When students are taught game elements, elements of the digital game interface, and digital incentives/failures simultaneously, they may surpass their cognitive threshold, resulting in ineffective learning. In addition, the neutrosophic theory acknowledges the uncertain nature of such complicated relationships and notes that with increasing complexity, uncertainty only increases.

5.3 The Relative Impact of Game Elements

The Implemented Game Elements (IGE) showed the lowest consistency (0.5869) and coverage (0.5985) values among the three factors studied. This finding provides a nuanced perspective on the role of traditional gamification components (points, badges, leaderboards) in educational contexts. While these elements contribute to reading habit formation, they appear less influential than technological integration or feedback mechanisms.

This result may challenge some prevailing assumptions in gamification literature that often emphasize game mechanics as primary motivational drivers [34]. Instead, our findings suggest that game elements might better serve as supportive features rather than as the central components of educational interventions aimed at developing reading habits.

5.4 Educational Implications and Recommendations

The findings from this neutrosophic analysis have several practical implications for educators and educational technology designers:

1. **Prioritize Integrated Feedback Systems**: Educational applications designed to promote reading should incorporate immediate, personalized feedback systems that respond to student interactions in real-time. The strong performance of the IF variable (coverage: 0.6786) suggests this should be a priority feature.

2. **Embrace Strategic Minimalism**: Rather than implementing numerous gamification elements simultaneously, educators might achieve better results by selectively implementing fewer, more carefully chosen components. The relatively lower effectiveness of the three-component combination suggests a "less is more" approach may be beneficial.
3. **Contextualize Digital Tools**: The high consistency value for ADT (0.6875) indicates that digital technology remains a powerful tool for reading promotion, but its implementation should be thoughtfully integrated with feedback mechanisms for maximum impact.
4. **Consider Student Individuality**: The neutrosophic approach used in this study acknowledges that educational interventions affect students differently. The varying degrees of truth, indeterminacy, and falsity captured in the original data reflect the individualized nature of learning responses that should inform personalized approaches to reading promotion.

5.5 Methodological Contributions

Beyond its substantive findings, this study demonstrates the value of neutrosophic set theory in educational research. The ability to capture indeterminacy through the third dimension (I) of neutrosophic logic provides a more nuanced understanding of educational phenomena than traditional binary or even fuzzy approaches allow. This methodological innovation offers a more realistic representation of the complex, often uncertain relationships between educational interventions and outcomes.

The fuzzy-set qualitative comparative analysis (fsQCA) approach, enhanced by neutrosophic logic, allows for the identification of multiple pathways to the same outcome (equifinality), aligning with the complex nature of educational processes. This methodological approach acknowledges that there is rarely a single "best practice" that works universally for all students in all contexts.

5.6 Limitations and Future Research Directions

While this study provides valuable insights, several limitations should be acknowledged. The sample size (15 students) is relatively small, which may limit the generalizability of findings. Additionally, the study was conducted in a specific cultural context (Ecuador), and cultural factors may influence how students respond to gamification strategies.

Future research could expand on these findings by:

1. Conducting larger-scale studies across diverse cultural contexts to test the generalizability of the observed relationships.
2. Employing longitudinal designs to assess the sustainability of reading habits developed through gamified interventions.
3. Exploring the specific mechanisms through which digital technology and feedback systems interact to enhance reading motivation and habit formation.
4. Investigating how different types of game elements (competitive vs. collaborative, extrinsic vs. intrinsic) might yield different patterns of effectiveness.
5. Examining how individual differences in students (learning styles, prior reading attitudes, technological familiarity) moderate the effectiveness of various gamification strategies.

In conclusion, this neutrosophic analysis reveals that the relationship between gamification strategies and reading habit development is complex and multifaceted. The findings suggest that educational interventions should be designed with careful attention to the synergistic effects of different elements, rather than if more gamification features will invariably produce better outcomes. By prioritizing the integration of digital technologies with immediate feedback systems, educators may create more effective pathways to developing sustainable reading habits among adolescent students [35,36].

6. Conclusions

This study provides a novel perspective on the interplay between gamification strategies and the development of reading habits among eighth-grade students by applying neutrosophic set theory within a fuzzy-set Qualitative Comparative Analysis (fsQCA) framework. The findings highlight that while traditional game elements—such as points and challenges—play a role, they are not sufficient on their own to foster consistent reading habits. Instead, the combination of applied digital technologies and immediate feedback systems emerged as the most influential and robust factors, especially when tailored to student contexts.

A key contribution of this work lies in its methodological innovation: using neutrosophic logic to capture the ambiguity, partial truth, and uncertainty present in educational responses. This approach allows for a more realistic and context-sensitive analysis, moving beyond binary or overly deterministic models of behavior.

From a pedagogical standpoint, the results underscore the importance of strategic minimalism in gamification design—prioritizing well-integrated, feedback-rich digital interventions over the simultaneous implementation of multiple game elements that may lead to cognitive overload.

The study also reinforces the idea that causal complexity is central to educational outcomes. Therefore, educators and designers should not only focus on which gamification elements to use but also understand how and under what combinations they work. Future research can build on this model by expanding the sample size, exploring cross-cultural applications, and incorporating longitudinal methods to assess the sustainability of reading habits over time.

Ultimately, this work contributes to the emerging field of Neutrosophic Educational Analytics, offering theoretical advancement and practical guidance for evidence-based, causally informed intervention strategies that can effectively foster student motivation and learning engagement in the digital era.

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