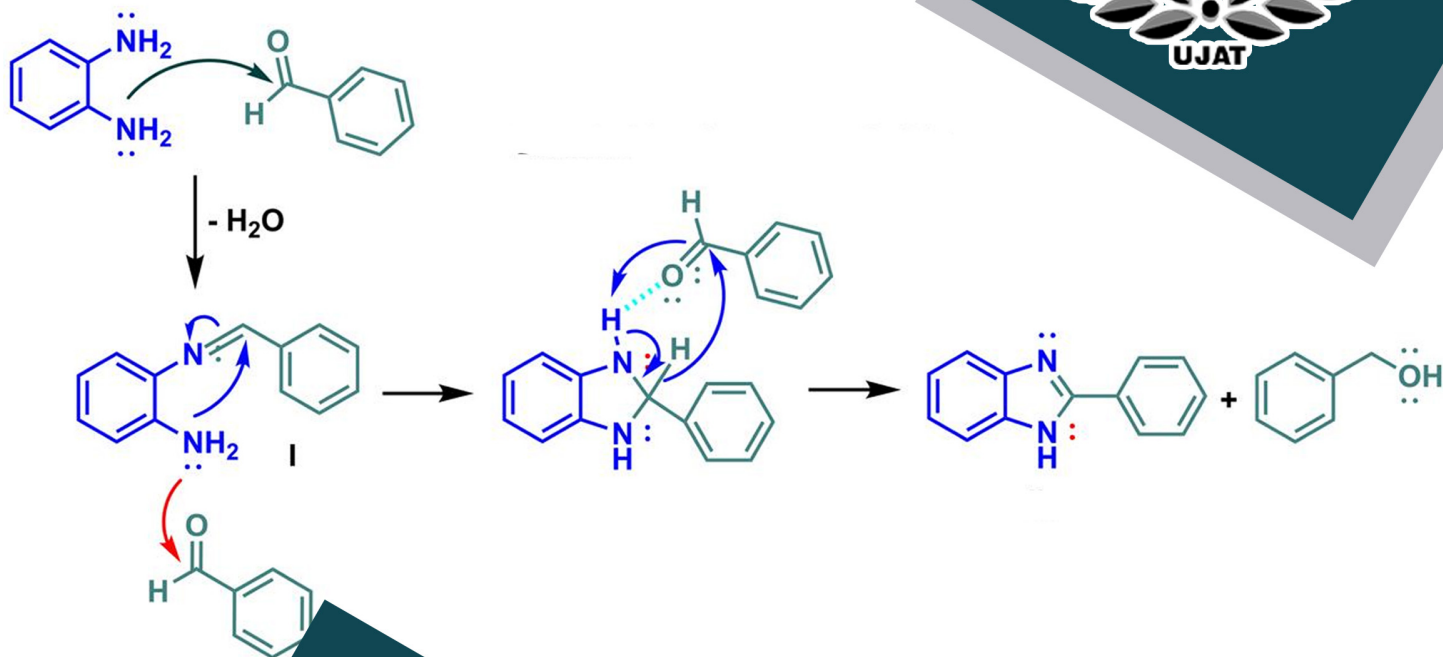




UJAT

UNIVERSIDAD JUÁREZ
AUTÓNOMA DE TABASCO

“ESTUDIO EN LA DUDA. ACCIÓN EN LA FE”



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En este número del Journal of Basic Sciences, se reúne un conjunto de resultados de investigaciones que, abarcando diversas áreas del conocimiento, presentan un punto de convergencia dado por la búsqueda de soluciones a diversos desafíos de nuestra realidad actual.

De esta forma, en el estudio sobre la gamificación sobre la enseñanza de las matemáticas, se presenta un acercamiento hacia la inclusión educativa, ya que se demuestra que mediante el uso adecuado de herramientas lúdicas y digitales es posible reducir la ansiedad y potenciar la autonomía en estudiantes con necesidades educativas especiales; señalando que la transformación de las aulas, hacia sitios en donde se fomente la participación activa de los estudiantes, se facilita enormemente mediante la aplicación adecuada de este tipo de estrategias.

En otro orden de ideas, la segunda contribución presenta una metodología basada en el principio de la química verde para la síntesis de benzimidazoles; empleando ultrasonido y aplicando un proceso que elimina el uso de disolventes nocivos, se llega a optimizar el tiempo de reacción, logrando buenos rendimientos. Siguiendo esta tendencia de optimización de procesos y aprovechamiento integral de recursos, en el tercer artículo se analiza el potencial de transformación microbiana del bagazo de malta de cebada; mediante la modificación planteada, se mejora la composición de este subproducto de la industria cervecera, lo que permite su aplicación hacia el desarrollo de alimentos funcionales.

La gestión adecuada del entorno es el tema central de dos contribuciones incluidas en este número. Por un lado, se presenta el uso exitoso de *Sagittaria lancifolia* para efectuar procesos de remediación de aguas residuales agrícolas en Tabasco. Por otro lado, se rescata la dimensión social a través de un estudio cualitativo de memoria ambiental, mediante la recuperación de narrativas locales sobre la erupción del volcán El Chichonal del año 1982, se destaca cómo los habitantes de la comunidad Aquiles Serdán dan significado a los cambios en su paisaje fluvial y agrícola, mostrando un registro de resiliencia que va más allá de los datos geológicos.

Por último, en dos artículos se abordan aspectos relativos a la salud pública y el impacto de contextos críticos. Así, se presenta un análisis sobre la prevalencia de anemia en estudiantes de nuevo ingreso en la UJAT, subrayando la necesidad de mantener una vigilancia epidemiológica constante que coadyuve a asegurar el desarrollo integral de los miembros de la comunidad universitaria. Por último, se incluye un estudio sobre los hábitos de sueño durante el periodo de aislamiento provocado por la pandemia de COVID-19, donde se advierten alteraciones psicológicas persistentes derivadas del confinamiento.

En síntesis, el conjunto de contribuciones que integra este número, ofrece un panorama en donde se muestra cómo la ciencia no solo busca la explicación de fenómenos aislados, sino que la aplicación del conocimiento científico lleva a la articulación de respuestas ante diversas problemáticas, en una búsqueda de una sociedad más sustentable y en equilibrio con su entorno.

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Efectividad de la gamificación en la enseñanza de matemáticas para estudiantes con necesidades educativas especiales

Effectiveness of gamification in teaching mathematics to students with special educational needs

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Resumen

Este estudio investiga los efectos de la gamificación en la educación matemática de estudiantes con necesidades educativas especiales (NEE) en primaria. Se adoptó el método cuasiexperimental, y 48 alumnos con NEE fueron asignados a un grupo experimental (n=25) con una intervención gamificada de 12 semanas y a un grupo control (n=23) con instrucción convencional. El enfoque lúdico se basó en herramientas en línea (p. ej., Classcraft, Kahoot!) y mecánicas de juego como puntos, niveles y desafíos cooperativos, alineadas con el currículo de matemáticas. El rendimiento matemático también fue evaluado mediante pruebas previas y posteriores, y las observaciones del profesorado registraron los niveles de participación. Los resultados revelaron una mejora significativa en el grupo experimental, con puntuaciones medias que aumentaron de 12.3 a 22.7 (sobre 40), en comparación con un aumento mínimo de 12.9 a 15.2 en el grupo control. El análisis estadístico también demostró un tamaño del efecto no superable (d de Cohen = 1.87) y la superioridad de la gamificación para mejorar el pensamiento lógico y la resolución de problemas. La participación activa mostró una alta correlación ($r = 0.72$) con las calificaciones, lo que demuestra una vez más los beneficios motivacionales de la gamificación. La retroalimentación cualitativa indicó una mejora en el ambiente de clase, una reducción de la ansiedad y una mayor autonomía estudiantil. Si bien el estudio es exitoso, identifica limitaciones como el muestreo y el tiempo de intervención. Sugiere estudios longitudinales, una demografía más amplia y la evaluación de la gamificación digital y analógica.

Palabras claves: *gamificación, necesidades educativas especiales, educación matemática, aprendizaje inclusivo.*

Abstract

This study investigates the effects of gamification in mathematical education for students with special educational needs (SEN) in elementary school. The quasi-experimental method was adopted, and 48 SEN students were assigned to an experimental group (n=25) with a 12-week gamified intervention and a control group (n=23) taught conventionally. The game-based approach drew on online tools (e.g., Classcraft, Kahoot!) and game mechanics like points, levels, and co-operative challenges that were aligned to mathematics curriculum. Mathematical performance was also assessed through pre- and posttests, and teacher observations tracked levels of engagement. Results revealed significant improvement in the experimental group, with mean scores rising from 12.3 to 22.7 (out of 40), compared to a minimal rise from 12.9 to 15.2 in the control group. Statistical analysis also proved an unovercome effect size (Cohen's $d = 1.87$) and the superiority of gamification to

improve logical thinking and problem-solving. Active engagement was highly correlated ($r = 0.72$) with grades, again demonstrating the motivational benefits of gamification. Qualitative feedback indicated improved class climate, reduced anxiety, and greater student autonomy. While the study is successful, it identifies limitations such as sampling and intervention time. It suggests longitudinal studies, wider demographics, and evaluation of digital and analog gamification.

Keywords: *gamification, special educational needs, mathematics education, inclusive learning.*

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1. Introduction

Mathematics education was never ever an easy task [1]. Not due to the fact that there is something about the subject matter that is excruciatingly complex, but due to the fact that maths has the power to induce fear, rejection, and alienation in the overwhelming majority of students. It is a maths phobia that runs through all education and cultural fronts; a feeling which crosses national frontiers and strikes the student at any stage of his educational career. In fact, the issues of the students while trying to learn mathematics are so common that they can be termed an epidemic across the globe. But for SEN students, the issue is all the more complex because they already possess other issues that complicate things and make it even difficult for them to learn mathematics. They possess cognitive challenges, emotional challenges, and behavioral challenges that render them incapable of understanding the regular curriculum, particularly the logic-mathematical mode of thinking [2]. Problems among SEN students are not just cognitive but are in their affective and psychological beings that match the level of their learning profiles. Chronic failure at performing numeracy tasks builds hopelessness with helplessness at being unable to manage it, reinforcing negative self-concepts and avoidance behavior [3]. Therefore, the challenge is to mold pedagogies which are able to link such students' potentialities with the requirements of the curriculum so that learning becomes inclusive and participatory [4].

The imperatives for the introduction of inclusive and participatory pedagogy. Teachers, instructors, are bound to create appropriate avenues for meeting the individual needs of all the students, such as SEN students, and granting them a level playing field to actualize their full potential. The conventional model of teaching is not sufficient enough to cater to the needs of different disabled students. Thus, the fraternity of teachers today is more aware than ever of the need for newer approaches such as differentiated instruction and tailored learning to develop inclusive classrooms for all children [4]. These approaches strive to develop a classroom climate that is not only academically goal-driven, but also emotional well-being, social belonging, and bonding. By facilitating interaction and participation, these pedagogical approaches have the potential to reduce the alienation inherent in learning mathematics for SEN students. This section discusses some of the most recent promising practices that have very recently become so highly trendy in dealing with such issues, such as gamification [2]. Gamification is possible to define as the application of game mechanics such as points, levels, rewards, and progress tracking—outside of games but in learning settings.

Gamification is the process of creating otherwise bland or interesting activities interactive, interesting, and immersive by employing the joy of the game naturally towards the goal of obtaining active attention, persistence, and indigenous motivation [5]. While traditional games are focused on drill and practice, gamification integrates these components of a game as part of the learning process, thereby making the latter interactive and interesting. This enables the students to learn the content at their convenience whenever they require it and track their progress over time. This works very well for learning mathematics, a field with which many students have traditionally struggled with either boredom or intimidation. With the incorporation of game-like elements into mathematics instruction, learning would be fun and permit

students to experiment, err, but learn mathematics better [6]. Numerous scholars have predicted gamification as a possible way in which learners can be sustained in motivation, focus, collaboration, as well as learning satisfaction as a whole [3]. Additionally, the competitive or collaborative gamification can be applied in the aim of eliciting cooperation, collaboration, and socialization among the students, thus maximizing the learning process. Because of this characteristic, gamification has succeeded in schools across the globe even in mathematics, a subject over the past decades that was unable to sustain the attention of students.

Nevertheless, although the positive impact of gamification has been the topic of numerous studies in ordinary classrooms, they have mostly been conducted among nondisabled children [3]. Existing research on gamification will thus be the voice of nondisabled students and much less likely to cover particular needs of learning disabled students or other students who have various special educational needs. This study explores to what extent gamification can be utilized to improve SEN students' motivation, engagement, and performance and its impact on math attitude. Further studies on how extensible gamified learning systems can be tailored to address the diverse needs of SEN students exhibiting cognition, emotional, and behavioral difficulties need to be performed [7]. The claim that gamification has been shown to offer as a solution for mathematics issues in learning of students with SEN is promising but will have to be within its limit and risk. Gamification is properly designed, innovative positioning within the curriculum, and with proper resources. The conditions of successful deployment are researched in three broad categories: Pedagogical Design, Teacher Training, and Technological Resources. Key Points to Keep in Mind for Successful Implementation.

1. Pedagogic and Curricular Design Effectively tuned gamification requires well-designed synchronisation with the level of learning objective and learning preference of SEN students:

- Alignment with Curriculum: It should be aligned with the requirement of the main maths curriculum in testing, problem-solving, mental maths, core maths, and logic.
- Narrative and Context: Narrative (story) and quest building are required to set the stage for presence in a learning existence frame.
- Error Management: Failure should be facilitated in the system as part of learning that keeps the affective cost of failure at a low level and leads to persistence and resilience.
- Process Attention: Positive reinforcement in the way of effort and progress rather than outcome, that is, very useful for SEN students who are repeatedly failing at school.
- Channels of Feedback: Feedback must be provided immediately so that the students know what was wrong they did and what do they have to do in order to rectify that and thereby generate motivation and feelings of achievement.
- Social Learning: Effort should not be made to segregate the students but offer social learning and feeling of belongingness since socio-emotional skills are developed by students with SEN through group activities.
- Individualized: Its application ought to be guided by continuous observation, feedback from students, and inclusion in study plans that are individualized.

2. Teacher Initiative and Motivation

Reflection practice is dependent upon the human factor

- Intentional Training: Teachers must be trained to design and build gamification of learning environments that are generalizable to the settings of their students.
- Effort Investment: It takes an incalculable level of pedagogical effort, imagination, and work from teachers to map curriculum subject matter onto game-like features in the enactment of a gamified intervention.

3. Technology and Access to Resources

The efficacy of the gamified strategy is with support-logistics:

- Technological Infrastructure: The schools are responsible for offering the technological infrastructure to ensure gamified learning reaches every student.
- Equity of Access: It should be made accessible to students irrespective of socio-economic status. Technical hardware is scarce in one of the top practical constraints, especially in poorer school districts.
- Suitable Tools: There needs to be availability of web-based tools and platforms with gamification capabilities, i.e., Classcraft, Kahoot!, and the Prodigy math game.

Teachers would also need training in the process of designing and setting up the gamified learning environment that is responsive to the needs of the students.

Apart from that, schools would also have the obligation of making sure all the students regardless of the socioeconomic background of the family possess the technological equipment needed for gamification learning [8].

All these aspects would have to be remembered while arriving at the impact and practicability of gamification as an inclusive learning process.

Gamification studies among education have been limited to only those students belonging to higher educational levels, i.e., university or secondary level [3].

Gamification usage at the elementary level and particularly of inclusive classes of SEN students has not been examined as yet. Also, methodological issues like small sample size, intervention durations being short, and ineffective use of mainstream measures will mostly taint research in the field [3]. Loopholes in this instance are in carrying out more controlled studies as a way of providing a better set of evidence on how gamification may be used in the effort to boost SEN students' performance in mathematics. SEN students face particular difficulties in learning mathematics, most of which are emotional and cognitive in origin.

For example, children with mathematical reasoning disorder, number sense and numerical processing disorder, and dyscalculia find it extremely difficult to understand mathematical concepts. Additionally, ADHD students do not have the ability to sustain attention on tasks for an extended period and therefore get distracted and cannot complete tasks [9]. Low frustration tolerance emotional dysregulation also makes it easy for such dysregulation to occur, hence demotivation or fear every time faced with difficult tasks [10]. These intellectual and emotional challenges of linguistic impairment also introduce additional barriers in mathematics problem-solving and comprehension [9]. Traditional pedagogical approaches are not designed for SEN students, as SEN students have been predominantly classified as "underachievers" in mathematics. Stigmatization will further result in low efficacy, avoidance, and failure [10]. Gamification is a new paradigm because it provides an adaptive and non-critical learning environment.

The greatest advantage is that it does not view mistake as something negative factor of the process of learning. Whereas in traditional classroom settings failure is not merely absence but also chips away at the confidence level of SEN students, in game-based learning systems the effort is rewarded and students are able to try out various solutions for problems without the threat of negative ramifications. Careful thought should be given to how game-based learning systems can be tailored to make them accessible to intellectually, emotionally, and behaviorally challenged SEN students. Herrera (2025) describes some of the most wonderful benefits of gamification in such a setting. The best benefit is that gamification does not dread failure because it is a component of learning. Though mistakes in regular classrooms can rob SEN students of their confidence, gamified environments motivate learners and allow students to try countless viable solutions without anticipating consequences. This type of environment reduces emotional pain at failure significantly, thus enabling the students to learn and get better [7].

Secondly, gamified environments promote effort and improvement as strongly as the result.

This shift in focus is best suited to SEN students who have encountered more than a study course failure previously because it serves to re-boost their motivation and self-belief, thus encouraging them to keep practicing. Through the conversion of failure into opportunity to learn and improve, gamification also calls for learner persistence and resilience. On a related but different context, gamification provides instant feedback, particularly beneficial for SEN learners. Instant feedback enables the learners to partake in where they went wrong and how they could better do it next time, hence a feeling of achievement and encouragement. This is in far contrast to traditional testing, where feedback arrives too late and does not get it right and has a high likelihood of resulting in frustration and disorientation. Although in the potential extremes of gamification, its implementation in real classrooms and particularly for SEN children is plagued by innumerable problems [11]. One of the greatest concerns is if gamification will be long-lasting for children with ADHD, who cannot focus on activities in the long run. Apart from this, even its use during intellectual development of intellectually disabled students is questioned, and there is no clear understanding if gamified learning systems can meet their intellectual demands to the maximum [12]. Gamification involves a collection of challenges requiring additional focus. It requires high-quality lesson planning, which would be difficult to be completed under normal classroom circumstances if teachers do not have training in gamification.

The second discouragement is the lack of technical infrastructure to enable effective implementation of the gamification project, which is extremely prevalent within schools in disadvantaged school districts.

These actual traps in practice create absurdly wide gaps between theoretical gamification uptake and the action that is followed in classrooms. The second biggest challenge has been to achieve a proper balance between collaborative interaction and individual learning within gamified learning. Though gamification veers towards individual learning, the strategy itself does not have to replicate, in exact words, that feeling of belongingness and unity that forms the foundation for effective inclusive education. Today, gamified interventions are not only designed to address improvement on an individual level but need also to incorporate social learning opportunities in a bid to avoid learner isolation from others during learning [11]. The affective aspect of gamification needs to be addressed in the right manner in a phase whose aim is the optimization of effectiveness of gamification as a learning intervention. Gamification may also be applied to guide the attitude towards failure of the learner in a manner in which failure is seen as part of learning and not in the guises of signs of weakness. This change of attitude is particularly important in the case of SEN students whose confidence to learn would otherwise have been lost due to their previous failure to learn. By orienting towards failure as a developmental and learning experience, gamification makes the learners obstinate and resolute [7].

Despite the vast potential of gamification, the majority of literature suffers from methodological shortcomings that minimize the findings to a lower generalizability.

The majority of the studies are post-test, no follow-up, no control groups, and short-term, and thus it is challenging to establish certain hypotheses on the basis of the long-term success of gamification [13]. Additionally, these studies only take into account the rise in academic achievement, without taking into account other related variables such as: Students' Attitude towards Mathematics; Emotional regulation; The construction of self-regulated learning. In order to build a comprehensive picture of gamification impacts, future research needs to take into account a broader set of outcome measures, e.g., qualitative information concerning the emotional and social growth of children [13]. This present study attempts to make its own contribution to special education gamification research by investigating the potential to enhance SEN elementary school students' mathematics achievement.

It is a step forward towards a more critical intervention in how gamification can be applied to the service of learning and inclusion through the use of quasi-experimental design, pre- and post-testing, and triangulation of quantitative and qualitative data. It is genuinely focused on pedagogic goals of equity,

individualization, and integrated development, especially for those students who previously had been excluded from processes of normal schooling [3]. There was a need for an early school (9-12 years) focus since it is where SEN students perform the worst in the whole curriculum, and that makes sense-logico-mathematical thinking. There was interference in developing top-level ability base for this age such as logical reasoning and problem-solving, and which was enhanced the most through gamification process. Above all, by that time, SEN students will already have had other math learning problems under below negative self-perceptions and generating high emotional tension; in such a case, gamification is optimally able to eliminate such psychological experiences by reframing mistakes as accomplishment and experience of learning and thereby recovering motivation and self-worth Background Gamification can be defined as the application of game design elements i.e., points, levels, rewards, and progress tracking—outside a game but prominently in education. The basic principle for employing this process is to leverage the inherent entertainment value of playing games so that otherwise stagnant or mundane tasks become more interactive, dynamic, and interesting. Gamification Effectiveness in Books There are various research studies that have offered proof of the gamification effect of increasing motivation, concentration, cooperation, and learning satisfaction [5], [6].

Gamification has been found to have a very positive effect on the motivation and performance of students, particularly on those activities in which they are failing right from the start [13]. Reward mechanics, points, and competitions in game design have been found to be wildly successful at maintaining the interest of students and at getting them to perform tasks that would have otherwise bored or intimidated them. Restricting the Research: In spite of the improving classroom trends, most of the existing research on the positive effect of gamification has been conducted on average classes and normally developing students. Most of the existing research does not reflect the life of the student with disability and thus restricts discussion regarding SEN or learning disability students' special needs.

Secondly, a lot of the investigation which has been done into whether gamification is effective has been on a university or high school level and above [3].

Gaps in the Field: This literature bias has led to a de facto knowledge gap as to whether gamification can be used to help students with SEN, and maths disability specifically.

The pedagogical potential of gamification as a main pedagogical tool and accompaniment in inclusive classrooms for students with special education needs is unexploited. Other than that, there are doubts as to whether gamification might allow students with disability to maximize math attainment and attitude [3]. Besides, serious methodological flaws have been reported in prior work:

1. Short-Term Strategy: There have also been some post-test follow-up process-less or control group-less short-term investigations, and it is difficult to make healthy long-term effect conclusions regarding gamification [3], [13].
2. Small Samples: It is vulnerable to issues of sample size and low application of standardized tests [3].
3. Unidimensional Outcome Orientation: It is the attempt of most of the research to boost academic performance but overlook powerful variables such as student mathematics attitudes, emotional selfregulation, and self-regulated learning.

These flaws in design and lack of guidance in the case of SEN students provide the basis for more controlled studies on the introduction of gamification and how it affects mathematics performance in SEN students. The present study aims to help address such research gaps in an investigation of the potential introduction of gamification as a tool to improve mathematics performance among elementary school SEN students.

The main hypothesis of this study is SEN students in the gamification intervention will be instructed more in mathematics than those in traditional teaching.

We also anticipate gamification to lead to greater emotional and motivational engagement, not only in performance but attitudinal shift of the learners in the process.

This presupposition is built upon flow theory [14] and self-determination theory, both of which assume fun, autonomy, and subjective competence as the pillars of quality learning.

The two theories then assume that fun, autonomy, and perceived competence must come before good learning.

Gamification is striving for such ideals on the back of the intrinsic fun of games with the hope of inducing active participation, persistence, as well as intrinsic motivation.

Specifically, the intervention utilized improvement visualization procedures (at points or levels) and immediate feedback to attempt to enhance students' self-improvement motivation and perceived competence. The intervention also promoted greater student autonomy perceptions, and encouraging inner motivation and greater emotional commitment desired by these theoretical models.

The research aims to evaluate the efficacy of gamification on elementary school students with SEN in learning mathematics. The specific objectives are to:

1. Compare the learning effects of students in the gamified intervention and non-gamified group.
2. Identify differences in math performance before and after the intervention; (3) explore the correlation between active engagement in gamified activities and academic performance.
3. Explore the attitudes of teachers regarding the viability of gamification in inclusive education.

2. Method

The research employed a quasi-experimental quantitative study design with a pretest-posttest control group design suitable for measuring up to the effect of an instructional treatment on a specific group where random assignment is not required, which has been relatively easier in actual classrooms where random variation of group assignment can be convenient or even ethical [15].

The investigation was conducted between March and May 2024 over a period of 12 weeks in three state schools within urban settings within southern Spain. Convenience sampling was applied in the selection of the schools since they already had inclusive education support rooms and there was institutional willingness to implement a research-intervention process. Each center had an in-house special education unit for students with diverse diagnoses, including autism spectrum disorders (ASD), attention deficit hyperactivity disorder (ADHD), intellectual disability-mild and moderate, and specific learning disorders (mainly dyscalculia and dyslexia).

The final sample included 48 SEN students, divided into two groups.: experimental (n=25) and control (n=23). Allocation was based on the natural distribution of available classrooms available in participating schools to avoid interference with school organization. Both cohorts were age-homogeneous (9 to 12 years), diagnosis category, math curriculum capacity level according to psycho-pedagogical report, and socio-economic level, according to orientation teams of education.

Independent variable was the application of gamification-based intervention to mathematics educational content. It included a sequence of gamified teaching that was designed by the research team and integration support teachers. It was designed based on the essential mathematics curriculum assessment needs with an emphasis on problem-solving, mental maths, core arithmetic, and logic. Practice online platforms with gamification features (e.g., Classcraft, Kahoot!, and Prodigy Math Game) and in-class environments with point systems, levels, badges, and group challenges.

The gamification task was presented in five phases: (1) introduction to game world, characters, and rules; (2) demonstration of maths resources within the vocabulary of missions; (3) construction of student- and team-centred gamified tasks; (4) symbolic rewards that offer feedback; and (5) embedded formative and

summative assessment within gameworld narrative. Sessions were 45-60 minutes, three weekly over the intervention duration.

The control group received the identical math content from the same instructors but with the same traditional approach to lecture presentation, reading from textbooks, and working formal paper problems. Both groups received the same time for mathematics instruction.

To measure the dependent variable—math performance—a 30 multiple-choice and 10 open-ended question standardized objective test was developed, already validated by mathematics and special needs education experts. Pretest and posttest were conducted with the test. Numerical ability, basic operations, problem solving, and logical reasoning were addressed by questions. Internal consistency analysis by the KuderRichardson coefficient (KR-20) of 0.87, which was high, determined the construct validity.

In addition to the quantitative measure tool, a purpose-built observation scale was utilized to record participatory action in the form of involvement, motivation, and persistence throughout the learning process. Administered by the support teachers at the end of each session, the scale utilized indicators such as sustained attention, co-operative interaction, independence in work, and persistence in error situations. Scores on this scale were used as an auxiliary variable to facilitate explanation of academic performance data and understand the motivational effect of gamification.

Parents'/guardians' consent was requested through an informed written consent form, with a guarantee of anonymity and confidentiality through the use of an alphanumeric coding system. Statistical analysis on SPSS (version 27) began with a test of normality through the Kolmogorov-Smirnov test. Since the results showed normal distribution in both samples, parametric tests were applied. Independent sample t-tests were employed to determine posttest means of experimental and control groups, and paired sample t-tests were employed to determine pretest and posttest scores for both groups. The level of significance was set at $p < 0.05$.

In addition to mean difference analysis, effect size was also calculated using Cohen's *d* and linear regression analysis to ascertain any possible relationships between levels of participation and academic performance in the experimental condition. Selection biases were minimized by uniform inclusion/exclusion, routine scheduling of sessions, and follow-up on dropouts and absences. There was 91.6% retention with four dropouts (two in each group) due to reasons external to the research.

Semi-structured interviews were one of the main qualitative tools to examine the gamification effects from the educator's perspective and not only quantifiable results, but also subjective emotions related to the process of pedagogical implementation.

The interview guide, structured in four thematic axes—general impressions regarding gamification, implementation experience, perceived impact on the students, professional reflection—allowed to gather an adequate number of experiences of high interpretative value. Interviews were either phone or face-to-face, generally 45 to 60 minutes. Participants were informed of the purpose of the research, confidentiality of response was assured, and informed consent to record was obtained. Interviews were transcribed verbatim with expressive nuances retained for subsequent analysis.

Qualitative analysis followed a thematic analysis path. The process began with exploratory reading of the transcripts and then open coding to determine salient discourse fragments. These codes such as "student motivation," "initial resistance," or "teacher creativity" were applied to produce interpretive categories. These comprised those fitting preconceived themes alongside some which arose naturally from the material, such as the relevance of pedagogical intuition or narrative as a pedagogical tool.

3. Results

Normality of the data was initially established using Kolmogorov-Smirnov test that provided significance values more than 0.05 in experiment group and control group for both pretest and posttest. This provided normal distribution of the data and thus use of parametric tests in subsequent comparison analysis was justified. Homogeneity of variances was also achieved using Levene's test that was insignificant ($p > 0.05$). There was a great variation between the pretest and posttest scores of the intervention group on the initial descriptive analysis. The mean was 12.3 out of 40 with a standard deviation of 3.6 prior to intervention, reflecting general poor function but with a little heterogeneity of cases. Following the gamification intervention, the mean score of the group was 22.7 points with a standard deviation of 4.2 and shows significant improvement, with no significant increase in data variability as a result of differential learning rates within the group.

Mean score for the pre-experimental control group was 12.9 (SD = 3.8) and was also given analogous conditions to the experimental group at the start of the experiment. Control group mean, though, rose to only 15.2 (SD = 4.1) on posttest, reflecting statistically significant intra-group improvement but significantly less than that for the experimental group. This was used to validate the hypothesis through showing extreme divergence in effectiveness for both methods of instruction.

To statistically confirm these results, paired sample t-tests were also used in both groups. In the experiment group, posttest minus pretest difference was highly significant ($t(24) = -13.18$; $p < 0.001$), while, in the control group, it was significant but of lower magnitude ($t(22) = -4.26$; $p < 0.01$). These results confirmed that both groups improved during the intervention period but with highly differing magnitudes in favor of the gamification method.

An independent samples t-test of posttests by group found a significant statistical difference ($t(46) = 6.53$; $p < 0.001$), with a large effect size of Cohen's d of 1.87. This is particularly significant, as it not only demonstrates that the experimental condition had significantly improved, but that its improvement had been significantly better than that of the control group even though they had started under essentially identical baseline conditions.

For comparison of the test items, the experimental group answered most rationally and on problem-solving, at 2.1 and 6.7, and 1.9 and 5.8 out of a maximum of 10, respectively. This would point towards the dynamic and contextual aspects of gamification (i.e., missions, challenges, and instant feedback) potentially enriching understanding, working through tasks, and attempts at inductive and deductive reasoning.

Improvement in daily tasks and mental arithmetic, while significant, was less pronounced, rising on average from 3.8 to 5.3, perhaps because the skills required more automatization than the short intervention could meet.

Semi-structured interview qualitative data corroborated trends in quantitative results. Definition of gamification, gamification implementation experience, perceived impact on students, and professional reflection were four thematic categories that comprised the interview guide. Staff noticed increased engagement and enthusiasm from students, particularly those with lower rates of these otherwise. A science teacher, for example, reported seeing students who had previously been sat apart on theoretical work getting involved enthusiastically in narrative-based problems put outside. One math teacher recalled a very successful escape-room-inspired assignment where students had to work through algebra problems in order to progress, with consequent mastery of concepts and enhanced peer interaction. Teachers also reported that gamification appeared to allow inclusion of students with learning difficulties; one dyslexic student, for instance, wrote more self-assuredly when assignments were reimagined as low-stakes "missions" with immediate feedback and symbolic rewards.

Teachers also reported challenges, especially at the beginning of implementation, which needed to be managed in time, imagination, and consistent reworking in order to incorporate curricular matter and ludic forces. However, they noted such challenges as short-term and swamped by passion and achievement seen within class. Transcript answers were transcribed verbatim and analyzed thematically, and clear convergence of conclusions with statistical findings, mainly motivation, behavior of collaboration, and class performance. Triangulation of the qualitative and quantitative findings thereby established that gamification affected cognitive and affective learning processes.

A second significant finding was the manner in which effort affected academic performance, as seen in teacher observation records. This test, administered several times during the 12-week intervention, assessed each student's effort in terms of endurance, teamwork, work, completion of tasks, and persistence. Linear regression provided a significant positive correlation between effort and end-test performance ($r = 0.72$; $R^2 = 0.51$; $p < 0.001$). It indicates that around 51% of variance in ultimate performance was explained by extents of participation in the gamified dynamic, consistent with the contention that investment and affect acquired through play has a causal influence on learning.

Individual students did so in some cases. For instance, an ADHD child raised his score from 7 to 21 due to persistent attention and interest in game-like stuff. One child with mild intellectual disability raised from 10 to 19, one of the most industrious members of co-operative work. These qualitative results corroborate the quantitative results in terms of saying that game-like intervention offered the real chance of the traditionally marginalised or at-risk students for this strand of curriculum.

The control group became better but less and less in a consistent manner. Others did a bit better even when consistently rewarded, while others were consistent, i.e., students with acute attention or reading comprehension deficit. Motivation was also less consistent among this group, excessive daydreaming, some passivity, or minimal activity in work assigned to them, just the opposite of the more active and lively mood seen among the experimental group.

It should be mentioned that not all the members of the experimental group were found to have performed much better. Posttest scores were identical or decreased by one point due to extraneous factors like poor attendance, emotional instability, or lack of proper encouragement in the home setting in four instances. These differences highlight the attention to the observation of the possible risks of oversimplification of outcomes and notice of the fact that though gamification is robust, it cannot correct all the issues of SEN students by itself. Heterogeneity of this population necessitates added measures and one-to-one support, not necessarily funded by gamification per se. Fidelity of implementation was obtained through systematic observation of the gamification elements introduced during each session (story, points scheme, levels, symbolic rewards, etc.). Outcomes showed high fidelity to the original design with 91.2% mean compliance and suggest that concrete effects are credibly causally attributable to the intervention. Instructors cited best times for engagement in badge rewards, peer competition for timed calculations, and story-based math discovery missions. Not only were these aspects contextualizing and engaging, but they also encouraged collaboration, tenacity, and recasting of failure in learning.

Though not the hoped-for outcome, changes in verifiable classroom attitude and affect were observed in academic self-concept and group cohesiveness. The very same students who had before been shy or intimidated by mathematics became more openly involved, seeking help without risk of rejection and even luxuriating in success that they did have, albeit in small degree. These qualitative findings, although not quantitated herein, were stringently noted by teachers and are essential to understanding the entire context of the finding.

4. Conclusions

The results of this study affirm that gamified methods of teaching mathematics offer an effective methodological key to achieving academic success in students with special educational needs. Throughout the research, this hypothesis was not only successful in regards to acquiring particular content but in changing classroom dynamics, building inner motivation, increasing emotional involvement, and the formation of positive attitudes towards education.

The hypothesis was to see if the integration of pedagogically designed playful and narrative features as a systematic component of a gamified product would have a differential impact, in contrast with the usual practice, on students with learning and engagement problems. The advantage was not just statistically significant to provide enhanced equity of access to mathematical understanding for traditionally disadvantaged learners.

It should be mentioned that neither exposure time nor practice repetition can be defined as the reason for improvement in the experimental group's performance. Instead, evidence supports the fact that narrative context, instant feedback mechanisms, visualization of advancement (via points or levels), and symbolic rewards were the reason for persistence, concentration, and students' interest in self-improvement. These were the areas overlooked by traditional methods, which used to conserve intellectual effort involved in problem-solving, logical thinking, and learning abstractions—historical weak points of the group. Qualitative data collected using semi-structured interviews supported and supplemented quantitative data, offering a complex understanding of how gamification affected not just academic performance but classroom culture and student identity.

Teacher reports indicated improvement in peer interaction, task engagement, and classroom climate, with specific reference to students who were formerly disengaged or socially withdrawn. That learners of varying cognitive and emotional profiles were involved in collaborative learning activities is a testament that gamification also has a mediating function of enabling social learning and inclusion, attesting to its further potential in facilitating inclusive education environments. Although the findings unequivocally establish the potential of gamification across a broad array of learning contexts, they also call for careful consideration of the conditions under which it can thrive.

First, the creation and implementation of a gamified intervention take an immeasurable amount of time, creativity, and pedagogical effort on the part of instructors. It is less about imposing inappropriately or artificially game-like elements and more about creating a sense of presence within a learning space that is also congruent with curricular goals and responsive to the needs of specific students. It deals with narrative development, quest development, and developing tracking and assessment mechanisms suitable to the class. It also addresses students' individual performance diversity within experimental groups with an explanation of internal student special needs' diversity. While others achieved outstanding, others achieved minimal or no achievement. This refers to heterogeneity that is to imply intricate interaction between contextual or personal characteristics such as attention disorder, socio-emotional problems, or lack of family support and instructional mode. It also emphasizes the problem that gamification, while extremely adaptable, must be read as part of a broader portfolio of differentiated strategies. To that extent, its application must be informed by ongoing monitoring, student feedback, and incorporation into individualized learning plans. Its boundaries must also be proclaimed in order to establish boundaries for its conclusions and guide subsequent refinement in the study of education. The first limitation is the short duration of the research period. Restricted to a single semester at university, sufficient to detect obvious differences between groups, future research will need to incorporate longitudinal studies evaluating longer-term retention of gamification impact and how it builds toward higher-order math ability or toward other segments of the curriculum.

A second limitation is sample size, which, while statistically adequate, was limited to a single education site with distinct sociocultural, institutional, and geographic characteristics. This limits the external validity of results to other school environments. Larger and more representative samples within schools in varying regions, socioeconomic levels, inclusion models, and diversity support levels would be required in future studies to enhance external validity and offer replicable trends.

The study had been aimed at academic accomplishment that had been quantified in content-testing terms and had not talked, to a greater degree, about the other dimensions of the students' holistic development, such as self-directed learning, academic self-concept, social contact, emotional stability, or sense of efficacy.

Although some of them were qualitatively observed and documented by interviewing teachers, they were not integrated into the systematic measurement plan. A high priority area for future research would be mixed-methods designs to measure quantitatively and qualitatively the gamification's many-sided effect on SEN students' school lives. In addition, one would need to develop and experiment with various gamification models in order to determine which particular components e.g., competitive versus cooperative formats, group versus individual-based advancement, or analog versus digital media have more powerful or long-lasting effects based on the learning profile. Breaking down these subtleties will be the way forward from promising results at the pilot project level to the development of evidence-based pedagogical models that can be replicated in a range of educational settings.

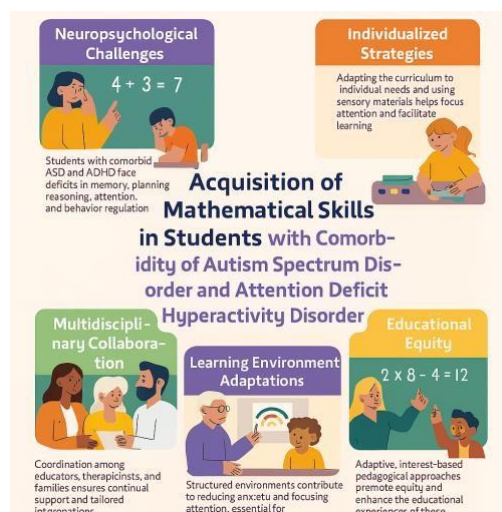
5. Conflict of Interest

The authors declare no conflict of interest.

6. Declaration of Use of Artificial Intelligence

The authors declare that they have not used any generative artificial intelligence applications, 512 software, or websites in the writing of the manuscript, in the design of tables and figures, or in the analysis and interpretation of the data.

7. Graphical abstract



8. Contributing roles

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