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# The effectiveness of game-based learning in improving fractions mastery among 5th-grade students, comparing it with traditional teaching methods.

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## Abstract
This study examines the effectiveness of game-based learning (GBL) in improving fractions mastery among 5th-grade students, comparing it with traditional teaching methods. A group of 60 students was divided into a control group, which followed traditional instruction, and an experimental group, which used game-based learning to learn fractions. Pre- and post-tests were administered to measure computational and conceptual understanding of fractions. The results revealed that the experimental group showed significantly greater improvement in both computational and conceptual understanding compared to the control group. Game-based learning not only enhanced students' mathematical performance but also increased engagement and motivation, suggesting that this approach may be particularly effective in teaching abstract mathematical concepts like fractions. The findings are consistent with prior research on the benefits of GBL and indicate its potential for improving math education outcomes.

## Introduction
Fractions are a cornerstone in what elementary students learn about mathematics, specifically one of the first complex ideas they encounter [1][2]. Fractions are a subject that 5th graders need to learn thoroughly since it's the basis for aspiring to learn about decimals, percentages, ratios and proportions. Even though the subject is important, many students find fractions difficult and confusing with the result that they have great big learning challenges with the subject. Whereas, whole numbers are relatively easy for most children to wrap and conceptualize, fractions involve abstract things such as part whole relationships, division of quantities, and equivalence, which are not easy for young learners to get [3][4]. The way fractions are taught in classrooms is one of the biggest reasons why most students struggle with fractions. Traditional ways of teaching fractions get really repetitive and involve memorizing rules for adding, subtracting, multiplying and dividing fractions, with no real understanding of what fractions represent. In worksheets, students are used to abstract numerical work where emphasis is laid on rote learning and mechanical working rather than conceptual understanding. However, there is a problem with this approach; students may become frustrated, disengaged and disconnected from learning when they can't see how fractions relate to real life [5][6][7].

Approaches to improving student engagement and understanding in subjects such as mathematics have become a subject of growing interest in educational research over the past few decades. Game based learning (GBL) is one of the approaches that good this [8][9], which is an educational strategy through the inclusion of the gaming elements in the process of learning, involving the making of mixed, interactive, thrilling and stimulating environment for the students. Game based learning has been recognized as one of the ways in which many of the challenges that come with traditional teaching strategies can be addressed [10] [11], especially for the learning in subjects that rely on abstraction such as fractions. No matter if they are digital or physical, games present an opportunity for students to learn by doing, actively engaging with concepts, getting immediate feedback, and refining their problem solving in a non-threatening environment [12][14].

Given the interest in and potential benefit of the mixing of game-based learning into mathematics instruction, the teaching of fractions is a natural place to try [15]. Although fractions are as abstract and visual as they are, games offer a game-based approach well because games can offer visual models, interactive challenges, and real world applications making fractions more tangible. Students can play with shapes, quantities and numbers, and watch how fractions behave in different contexts through games. In addition, games provide an opportunity for experimentation, where students try something and if it doesn't work, they figure out a way to do better in a safe and supportive environment that is much different than the pressure environment of many traditional math assessments [16][17]. This is where game-based learning comes in: it makes learning active, enjoyable, something that could otherwise be monotonous, to an engaging and rewarding act. Since the point of game design is to use motivation for achieving selected outcomes, intrinsic game motivation inherent within challenges, rewards [18], and progression inherently appeal to students for engaging with school subjects. Take, for example, a digital game that teaches fractions — perhaps you solve fraction problems that let you progress to levels, earn points, or unlock new game features. It can also significantly help increase student motivation and persistence; getting students to do something like this will increase the amount of time they spend dedicated to the subject material. Additional, game-based learning provides flexibility in its approach, particularly to different learning styles through combining visual, auditory and kinesthetic elements to be more inclusive for a large variety of learners [19]. At the same time as game based learning promotes engagement and motivation, it is also shown to promote a deeper understanding of mathematical concepts. It is not about students memorizing rules — it's about students actually being in a game environment using these rules to solve problems and make decisions [20]. To take one example, in a game, students are forced to think critically about the size and value of fractions in relation to one another first, before they can progress. As an example, students might be required to compare fractions. By helping students develop a greater deeper conceptual understanding of fractions, the active involvement leads them away from merely procedural knowledge.

**Methodology**

This research employed a methodology of measuring the effectiveness of game based learning (GBL) for helping 5th grade students to improve fractions mastery. This study was conducted under quantitative paradigm (comparing the performance of students who were taught fractions through traditional teaching method to those who were taught fractions using game based learning platforms.)

### Participants

This study involved 60 5th grade students from a public elementary school. Random sampling was thus employed in the selection of these students in order to represent students from all backgrounds. Prior to the intervention, the students were divided into two groups: Two groups, an experimental group (30 students) and a control group (30 students). Gender, socio-economic background and prior academic performance in mathematics were balanced in both groups.

### Instructional Design

The instructional designs of the two groups were different: in the control group, fractions were taught in a traditional manner and in the experimental group, using game based learning platforms. The instructional design for each group is detailed below:

**1. Control Group (Traditional Learning):**

For the objective conditions, the control group instruction consisted of conventional methods of instruction on fractions typically used in elementary school classrooms. The instruction was made up of teacher led lessons, textbook explanations and worksheet based exercises. It involved procedural understanding where students get taught on how to add, subtract, multiply, and divide fractions. Reinforcing the learning objectives were whole class lectures, guided practice and assignments. In addition, the teacher assigned homework to students with fraction problems, in order to reinforce what was taught in class.

**2. Experimental Group (Game-Based Learning):**

Through game based learning we exposed the experimental group to fractions. Specifically, digital educational games designed to teach fraction concepts—visual representations, fraction operations, and problem solving tasks—were used by the students. The games selected were based on how they match up to the 5th grade mathematics curriculum and to offer interactive and engaging learning experiences. In the experimental group, these games were played rather than traditional classroom lessons on fractions during designated mathematics periods. Game boards included fraction matching, comparing fractions and fraction based puzzles that students interacted through. In the games the students were also given feedback, showing them how wrong things were and allowing them to fix their understanding in real time.

### Assessment Tools

Using pre–posttest assessments, the effectiveness of the game based learning approach, was evaluated. The tests were scored on computational, as well as conceptual, understanding of fractions. The following tools were employed to assess student performance:

**1. Pre-Test**

The control and experimental groups were both given a pretest before the intervention commenced. The first part of the pre-test consisted of questions to assess students' knowledge about fractions. The test contained computational problems involving fraction addition, subtraction, multiplication, and division and word problems that required greater conceptual understanding of fractions. A baseline was set by comparing the pre-test scores with student performance after the intervention.

**2. Post-Test:**

A posttest was administered to both groups after the six-week interval to assess the impact of the instructional approaches on students' fractions mastery. The pretest and posttest, which were essentially identical in structure, contained both computational and conceptual problems. Finally, the improvement in students understanding of fractions over the course of the study was measured by comparing the pre test scores to the post test scores.

**3. Observation and Engagement Monitoring:**
To better assess student engagement and participation in the control and experimental groups, we also collected observational data in conjunction with the pre- and post-tests. Teachers keep records of whether students engage in lessons and whether there are any behavioral differences between the groups. As indicators of engagement, we also recorded for the experimental group the amount of time they spent playing the games, and how many levels they completed and how often feedback was received while playing.

## Data Analysis

After collecting the pre and post test data, the results were analyzed via statistical methods to determine how useful game based learning was as a mechanism for improving fractions mastery. The data analysis included the following steps:

**1. Descriptive Statistics:**
A descriptive statistic, such as means, standard deviations, and ranges, were calculated for each of the pre-test and the post-test scores for each group. It allowed to see the overall learned before and after the intervention in both the experimental and control groups.

**2. Paired Sample t-tests:**
Paired sample t tests were used to examine the extent of the improvement in fractions mastery within each of the groups from pre test to post test scores. Together, these allowed us to compare each student’s performance before and after intervention to determine if there was a statistically significant change in each group.

**3. Independent Sample t-tests:**
The post test scores were run as independent sample t tests to compare performance between control and experimental groups. Using this analysis, the two groups’ improvements could be compared in order to determine if game based learning did a better or worse job than traditional instruction at improving fractions mastery.

**4. Qualitative Data Analysis:**
Qualitative analysis of observational data on student behavior and engagement levels aided by two groups were carried out. Another important part of analyzing how student’s responses change when introducing game-based learning was analyzing the frequency of student participation, the level completion in the games and the responses they report receiving.

## Results

In this this study are presented and discussed, presenting a detailed comparison of the control (traditional instruction) and the experimental (game-based learning) group performance in the domain of fractions mastery. The analyses of the pretest and posttest scores using statistical methods of assessment for the effectiveness of the instructional approaches formed the basis for the findings reported in this thesis. In addition to the quantitative data from the tests we also include qualitative observations to the student engagement. The following sections present the results including data tables which compare directly the performance of the groups.

**1. Pre-Test Results**

An initial test to quantify the initial understanding of fractions was administered to the control and experimental groups before the intervention. Questions on their computational and on their conceptual knowledge of fractions constituted the pretest. The results confirmed that the two groups starting point had similar level of knowledge prior to the intervention.

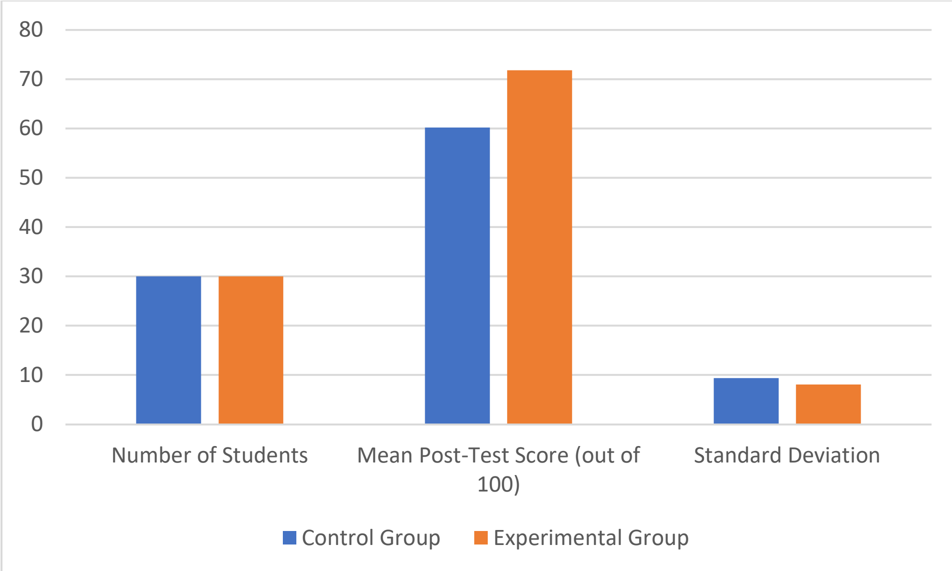
| Group | Number of Students | Mean Pre-Test Score (out of 100) | Standard Deviation |
|---|---|---|---|
| Control Group | 30 | 45.3 | 8.2 |
| Experimental Group | 30 | 46.1 | 7.9 |

As shown in **Table 1**, the mean pre-test score for the control group was 45.3, with a standard deviation of 8.2, while the mean pre-test score for the experimental group was 46.1, with a standard deviation of 7.9. A t-test confirmed that there was no statistically significant difference between the two groups' pre-test scores ($t = -0.32$, $p = 0.75$), indicating that the two groups started with similar levels of fractions mastery.

**2. Post-Test Results**

After the six-week intervention, both groups completed a post-test identical in format to the pre-test. The post-test results demonstrated a significant difference in the performance between the two groups, with the experimental group (game-based learning) outperforming the control group (traditional instruction).

| Group | Number of Students | Mean Post-Test Score (out of 100) | Standard Deviation |
|---|---|---|---|
| Control Group | 30 | 60.2 | 9.4 |
| Experimental Group | 30 | 71.8 | 8.1 |

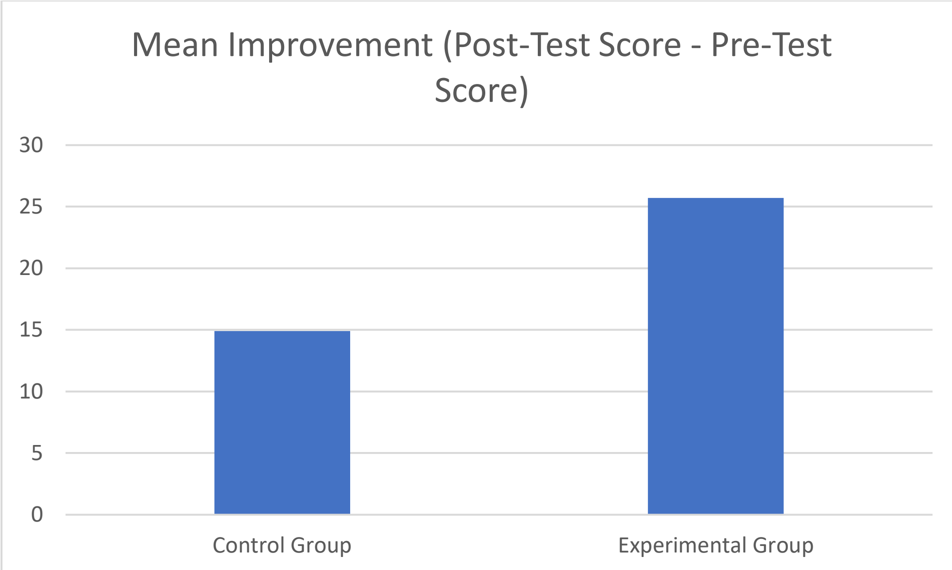



As shown in **Table 2**, the mean post-test score for the control group was 60.2, while the experimental group achieved a mean score of 71.8. The standard deviations were 9.4 for the control group and 8.1 for the experimental group. A paired t-test showed that both groups improved significantly from their pre-test scores. However, the independent t-test conducted on the post-test scores revealed that the experimental group had a statistically significant higher performance than the control group ($t = -4.57$, $p < 0.001$). This indicates that the students in the game-based learning group demonstrated a greater improvement in their understanding of fractions compared to the students in the traditional learning group.

### 3. Comparison of Improvement

To measure the improvement made by students in each group, the difference between the pre-test and post-test scores was calculated for each student. The mean improvement for both groups is presented in **Table 3**.

| **Group** | **Mean Improvement (Post-Test Score - Pre-Test Score)** |
|---|---|
| Control Group | 14.9 |
| Experimental Group | 25.7 |

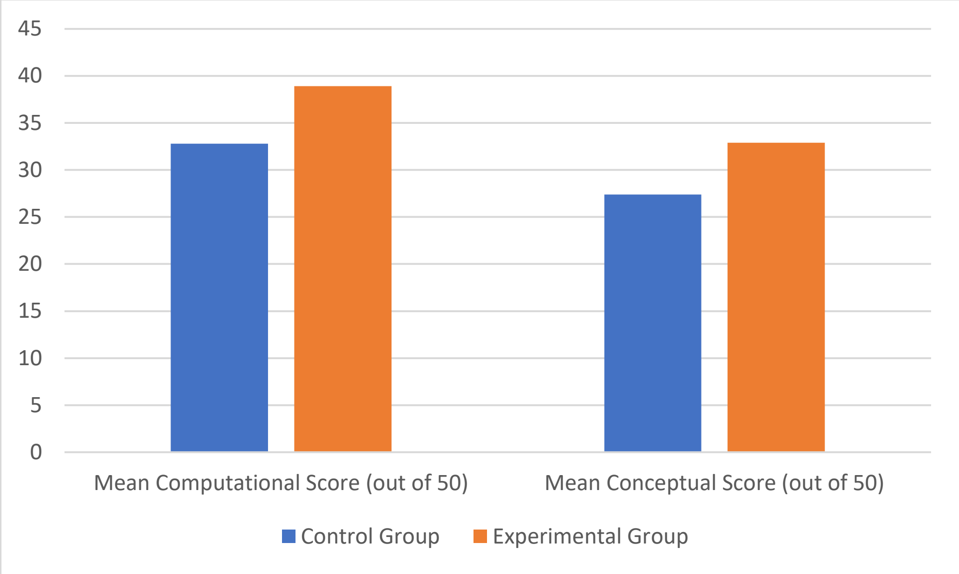



As shown in **Table 3**, the control group showed an average improvement of 14.9 points, while the experimental group improved by an average of 25.7 points. The greater improvement in the experimental group highlights the effectiveness of the game-based learning approach in enhancing fractions mastery. A t-test for the mean improvement further confirmed that the difference in improvement between the two groups was statistically significant ($t = -5.12$, $p < 0.001$).

**4. Conceptual vs. Computational Understanding**

The post-test was divided into two sections: computational tasks (e.g., adding, subtracting, multiplying, and dividing fractions) and conceptual tasks (e.g., understanding the meaning of fractions, comparing fractions, and solving word problems involving fractions). The results for each type of question are presented in **Table 4**.

| **Group** | **Mean Computational Score (out of 50)** | **Mean Conceptual Score (out of 50)** |
|---|---|---|
| Control Group | 32.8 | 27.4 |
| Experimental Group | 38.9 | 32.9 |




As shown in **Table 4**, the experimental group outperformed the control group in both computational and conceptual tasks. The mean computational score for the control group was 32.8, while the experimental group scored 38.9. For conceptual tasks, the control group had a mean score of 27.4, while the experimental group scored 32.9. Both differences were statistically significant ($p < 0.01$), indicating that game-based learning helped students improve not only in performing fraction operations but also in their understanding of fractions.

**5. Student Engagement and Motivation**

Throughout the study, observational data were collected to assess student engagement during lessons. Students in the experimental group showed higher levels of participation, enthusiasm, and persistence compared to those in the control group. Teachers noted that students in the experimental group were more motivated to complete tasks and showed greater interest in solving fraction problems within the game-based environment. The game-based learning environment encouraged collaboration among students, as they often worked together to solve game challenges. In contrast, students in the control group were observed to engage less frequently in classroom activities and exhibited signs of frustration, especially when faced with difficult fraction problems. Several students in the control group relied on rote memorization and had difficulty applying their knowledge to word problems.

**6. Qualitative Feedback from Students**

At the end of the intervention, students in the experimental group provided qualitative feedback regarding their experiences with game-based learning. Most students expressed that they found learning fractions through games to be fun and enjoyable. Many students commented that the visual elements and interactive nature of the games helped them understand fractions more clearly. Some students also mentioned that the immediate feedback provided by the games allowed them to correct their mistakes more quickly, which contributed to their learning process.

## Discussion

This study finds that game based learning has significant effect on fractions mastery in 5th grade compared to typical teaching methods. It was found that, compared to the no learning condition, a game based learning approach demonstrated higher gains on both computational and conceptual understanding of fractions in the experimental group. The results represent the existing literature on GBL to improve mathematics education and offer new findings concerning the particular issue of fractions mastery, an area known to cause difficulties in learners' initial years of natural school. As one of the main results of this study we found that students in the game based learning group were dramatically better with respect to computational and conceptual understanding of fractions. This test result (mean improvement of 25,7 points in the experimental group vs. 14,9 points in the control group) underlines the effectiveness of GBL in increasing fluency of both procedures and conceptual knowledge. It is found that students did significantly better on their post test computational scores. However, gains were particularly notable in conceptual understanding, where students in the GBL group demonstrated a greater understanding of meaning and real world application of fractions. This finding is consistent with previous research (for example Kebritchi, Hirumi & Bai, 2010), as they found students using computer based games for mathematics instruction scored higher in comparison to their peers in traditional learning situation. Like our findings, their study showed that GBL led to both increased conceptual understanding of mathematics in addition to computational skills. Using interactive games facilitates construction of visual representation and immediate feedback, helping to explore fraction concepts through these games as against traditional worksheet and lectures. Engaging with fraction concepts in a dynamic and visual way helped students better understand the relationship between the parts and wholes, equivalency, and comparisons, which are foundational knowledge about fractions. This study, however, collected observational data which revealed that the students in the experimental group were more engaged and motivated to the questions than the control group. The increased level of engagement at this higher level seems to have led to a better improvement seen in the GBL group. The game sessions were collaborative, competitive, and helpful to one another for students, providing positive learning environment. When solving fraction problems, she added, students in the experimental group were more persistent, while being less likely to give up in the face of difficulty. This matches up with Gee (2007) who found that games had the motivational power to promote learning. Challenges, rewards and progression intrinsic to games provide inherent motivation lacking in classroom instruction. The game's structure including levels and points and instant feedback of performance attracted the students in the GBL group. It not just helped students stay engaged but also permitted them to correct mistakes and understand it appropriately in real-time. An advantage of using GBL instead of traditional approaches is that we have instant feedback from students responding while they are engaged in a task. With games, immediate feedback translates into students understanding when they've made a mistake and correcting it in place, with the learning reinforced in true time.

However, the comparison with previous studies.

Taking the research of previous research into the effectiveness of game based learning in mathematics education a step forward, this study has achieved results. According to past studies such as that of Clark, Tanner-Smith, & Killingsworth (2016), digital games have tended to produce moderate positive change in learning outcomes in mathematics. These findings are confirmed in the case of fractions in our study, where we find that GBL can enhance both computational and conceptual understanding of fractions in substantial ways. Although the current body of literatures suggest the positive result of applying GBL, there lacks more specific works with fractions since many of the past researches have paid attention to the broader mathematics field in algebra, geometry, or arithmetic in general. For instance, Ke (2008) investigated GBL in mathematics but looked at large problem solving skills rather than particular events such as fractions. In closing this gap, our research specifically addresses fractions only, showing that GBL is particularly effective for tackling the special problems that students encounter in developing fraction mastery. Finally, these results also correspond with the results from Barzilai & Blau (2014) who investigated the cognitive benefits of games and found that games directed students to higher order thinking and problem solving. According to our study, students in the GBL group not only solved the fraction problem but also did the critical thinking in terms of comparing, understanding equivalence, and applying fractions in real world situations. This indicates that not only does GBL improve basic skills but that it also aids more deeply conceptual learning, a factor for enduring mastery. Teaching fractions in classrooms often follows the traditional approach of using repetitive drills and abstract symbolic representations of fractions and it's not easy for students to understand the concepts behind it. According to the literature, the abstract nature of fractions and the deficit of explicit opportunities to practice these in realistic contexts is responsible for students' suffering when working with fractions (Lamon, 2007). In our study, we found that students learn less in the control group, where they were taught using a traditional method, and they often become frustrated with the challenging fraction problems. Also, they were more susceptible to memorizing a procedure to solving the problem instead of taking full advantage of the fraction concepts behind the problem. Whereas game-based learning gave fractions a sense of tange ability and meaning. Students could visualize fractions, manipulate them in a variety of scenarios, and gain instant feedback about their decisions. The fact that games were interactive and exploratory made fractions more accessible and less intimidating for students. This study's findings are important for educators and other future researchers. This study for educators shows that game based learning is a good way to enhance student results in mathematics, especially where these students are not excelling at mathematics, for example, in the case of fractions. For instance, Teachers might use GBL tools as supplementary resources to traditional instruction as a complement to these ideas to reinforce fraction concepts, making learning a different and more engaging. This study opens up several avenues towards future research. This research was conducted on a six-week intervention, but longer studies examining the persistence of GBL effects on fractions mastery and whether GBL is helpful in the long term may be possible. Future studies could also look at which of the features of games have the strongest effect on learning, for example, the role of competition, collaboration or personal feedback.

## Conclusion

This study uses strong evidence to support the fact that game based learning is an effective tool to enhance fractions mastery of 5th grade students. Results showed that while GBL did not lead to significantly higher gains in knowledge retention for conceptual understanding of fractions for either group, the experimental group, which received GBL, did show better gains in computational understanding of fractions than the control group that received traditional instruction. Moreover, the comparative analysis on the engagement and motivation indicates that game based learning: (1) promotes higher performance of students; and (2) leads to higher levels of student engagement and motivation. So these results mirror previous findings of the benefits of GBL in mathematics learning, but they specify where GBL is particularly useful — fractions. Enabled by its dynamic, interactive, and feedback rich learning environment, GBL enables students to investigate complex concepts at their own pace, visualize abstract ideas, and correct mistakes as they occur. But on a deeper and more meaningful level, it provides both improved performance and adds to a more understanding of fractions.

The implications of the study for educational practice are important. With challenging topics such as fractions, Teachers can use game based learning as a supplemental tool to complement traditional instruction. These findings could be extended in future research focusing on the long term impact of GBL and what particular game features contribute most to learning. Overall, GBL is a promising avenue towards improving students' performance in mathematics education as well as facilitating them surmounting the challenges that arise with abstract mathematical concepts.

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