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The Impact of Management of Interactive Learning Environments on Mathematical Proficiency: A Neutrosophic Overview

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ABSTRACT: This study explores the influence of management of interactive learning environments on mathematical proficiency, leveraging a neutrosophic framework to account for indeterminacy and the neutral aspects of knowledge. Traditional learning environments often overlook the individual variations in cognitive and emotional engagement among students, potentially impacting their mathematical understanding and problem-solving abilities. By integrating the management of interactive technologies, such as educational software, gamified learning platforms, and virtual manipulatives, this research aims to enhance student engagement and proficiency in mathematics.

Key Words: Interactive learning environment, mathematical proficiency, neutrosophic set.

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1. Introduction

Mathematics is a crucial subject that underpins many fields such as science, technology, engineering, and finance. It equips individuals with essential skills like analytical thinking, problem-solving, and logical reasoning, which are vital in both academic and real-world scenarios. Despite its importance, many students find mathematics challenging and uninteresting, possibly due to traditional teaching methods that often rely on rote learning and repetitive exercises.

The evolution of pedagogical theories and educational technologies offers new opportunities to enhance math instruction. Interactive learning environment, characterized by the use of digital tools, collaborative projects, and personalized learning, present a promising alternative to traditional methods. These environments leverage technology to create dynamic and engaging experiences, aiming to make learning more effective, accessible, and enjoyable.

Neutrosophic sets were first introduced by Smarandache ([8], [9]) in the year 1990 as a way to deal with uncertainty, contradictions, and incomplete information. Over time, many researchers have expanded its real-world applications in different fields like decision-making, engineering, artificial intelligence, medical diagnosis, and social sciences. Scholars like Aslam [10] have applied it in quality control, Broumi [11] in multi-criteria decision-making, Ye [12] in decision sciences, and Biswas et al. [14] in optimization techniques. Their contributions have made Neutrosophic theory a useful tool for solving practical problems in various domains.

This study focuses on the impact of interactive learning environments on middle school students' mathematical proficiency, employing a neutrosophic approach to account for indeterminate factors and neutral knowledge. It seeks to determine whether the integration of technology and collaborative teaching strategies can enhance students' understanding, engagement, and overall performance in mathematics. The findings of this study could inform educational policies and practices, ultimately leading to improved math education outcomes.

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2. Literature Review

Numerous studies across various academic fields have highlighted the benefits of interactive learning. Strategies such as collaborative projects, the use of digital tools, and individualized learning pathways have been shown to promote higher engagement and better academic results.

Research by Johnson and Johnson [1] provides strong evidence that collaborative learning can enhance academic performance and problem-solving skills. Their study found that students in cooperative learning groups performed better academically than those in individualistic learning settings. This collaborative approach encourages students to work together, share ideas, and support each other's learning, resulting in a more comprehensive and effective educational experience.

Similarly, Smith et al. [2] examined the effects of integrating technology into the classroom. Their findings suggest that the use of digital tools like interactive software and online resources can boost students' motivation and engagement. By incorporating technology into the classroom, teachers can create dynamic and interactive learning experiences that captivate students and increase their enjoyment of learning. This study demonstrated how technology can transform traditional teaching methods and enhance student learning outcomes.

While the benefits of interactive learning have been demonstrated in various subjects, there is a lack of research specifically investigating the impact of these approaches on mathematical proficiency. Although broad research on interactive learning provides valuable insights, more targeted studies are needed to explore how these methods influence students' mathematical understanding and performance.

This study aims to fill this knowledge gap by providing empirical evidence on the effectiveness of interactive learning environments in math education, through the lens of neutrosophic logic. It seeks to determine whether the use of digital tools, collaborative projects, and personalized instruction can improve students' mathematical proficiency. The findings could inform educational policies and practices, leading to better math education outcomes and better preparing students for the challenges of the modern world.

3. Methodology

Participants

A diverse sample of 74 middle school students from different socioeconomic backgrounds was selected for this study. Participants were randomly assigned to either the experimental group, which utilized interactive learning resources, or the control group, which followed traditional teaching methods. The neutrosophic perspective was employed to account for uncertainties and indeterminacies in students' backgrounds and learning environments.

Materials

The interactive learning resources included digital platforms such as Khan Academy, GeoGebra, and Mathletics. These platforms offer various resources, including interactive simulations, educational videos, and personalized learning pathways. Neutrosophic logic was applied to evaluate the indeterminate elements in the selection and effectiveness of these materials.

Procedure

The study was conducted over six months. Both groups took a pre-test to assess their initial mathematical proficiency, acknowledging the inherent uncertainties in measuring true competence. The experimental group engaged in interactive learning sessions twice a week, while the control group received traditional instruction. At the end of the study, both groups completed a post-test to measure improvements in their mathematical skills, with neutrosophic sets used to interpret the variability in outcomes.

Group A [Pre]	Group A [Post]	Group B [Pre]	Group B [Post]
T I F	T I F	T I F	T I F
(0.74, 0.16, 0.1)	(0.72, 0.09, 0.09)	(0.63, 0.38, 0.3)	(0.58, 0.19, 0.16)
(0.6, 0.43, 0.25)	(0.73, 0.23, 0.29)	(0.6, 0.15, 0.01)	(0.72, 0.34, 0.21)
(0.55, 0.11, 0.37)	(0.79, 0.12, 0.31)	(0.52, 0.42, 0.44)	(0.56, 0.33, 0.14)
(0.71, 0.44, 0.29)	(0.88, 0.18, 0.01)	0.53, 0.45, 0.13)	(0.59, 0.38, 0.35)
(0.52, 0.06, 0.18)	(0.79, 0.37, 0.21)	(0.67, 0.44, 0.14)	(0.51, 0.02, 0.41)
(0.54, 0.19, 0.2)	(0.96, 0.39, 0.36)	(0.57, 0.2, 0.5)	(0.76, 0.05, 0.33)
(0.69, 0.37, 0.17)	(0.74, 0.24, 0.17)	(0.52, 0.41, 0.27)	(0.5, 0.19, 0.25)
(0.73, 0.48, 0.29)	(0.67, 0.04, 0.11)	(0.69, 0.1, 0.01)	(0.63, 0.26, 0.18)
(0.68, 0.14, 0.25)	(0.86, 0.05, 0.1)	(0.72, 0.2, 0.39)	(0.72, 0.1, 0.07)
(0.67, 0.18, 0.07)	(0.97, 0.02, 0.15)	(0.71, 0.34, 0.04)	(0.57, 0.11, 0.14)
(0.5, 0.15, 0.19)	(0.89, 0.14, 0.27)	(0.64, 0.2, 0.07)	(0.67, 0.15, 0.4)
(0.63, 0.37, 0.18)	(0.66, 0.1, 0.02)	(0.56, 0.1, 0.29)	(0.53, 0.01, 0.14)
(0.63, 0.46, 0.32)	(0.87, 0.33, 0.11)	(0.52, 0.27, 0.29)	(0.58, 0.29, 0.13)
(0.69, 0.39, 0.48)	(0.71, 0.1, 0.08)	(0.64, 0.15, 0.28)	(0.68, 0.12, 0.32)
(0.67, 0.17, 0.18)	(0.69, 0.11, 0.29)	(0.7, 0.03, 0.3)	(0.63, 0.27, 0.16)
(0.7, 0.18, 0.32)	(0.84, 0.22, 0.14)	(0.63, 0.16, 0.33)	(0.61, 0.21, 0.37)
(0.72, 0.39, 0.14)	(0.74, 0.16, 0.07)	(0.67, 0.18, 0.38)	(0.57, 0.42, 0.18)
(0.63, 0.09, 0.49)	(0.99, 0.02, 0.31)	(0.5, 0.2, 0.22)	(0.58, 0.2, 0.13)
(0.53, 0.29, 0.46)	(0.81, 0.43, 0.26)	(0.65, 0.05, 0.16)	(0.71, 0.21, 0.32)
(0.53, 0.17, 0.43)	(0.66, 0.32, 0.29)	(0.65, 0.41, 0.27)	(0.52, 0.13, 0.17)
(0.5, 0.39, 0.4)	(0.88, 0.42, 0.14)	(0.56, 0.37, 0.39)	(0.52, 0.31, 0.27)
(0.75, 0.26, 0.16)	(0.95, 0.39, 0.23)	(0.56, 0.02, 0.32)	(0.73, 0.05, 0.15)
(0.67, 0.05, 0.2)	(0.8, 0.08, 0.2)	(0.61, 0.11, 0.18)	(0.58, 0.26, 0.05)
(0.71, 0.15, 0.25)	(0.82, 0.35, 0.35)	(0.51, 0.19, 0.39)	(0.67, 0.27, 0.13)
(0.59, 0.43, 0.05)	(0.93, 0.12, 0.17)	(0.58, 0.2, 0.24)	(0.71, 0.19, 0.17)
(0.57, 0.44, 0.48)	(0.97, 0.37, 0.05)	(0.62, 0.09, 0.29)	(0.56, 0.12, 0.08)
(0.62, 0.29, 0.16)	(0.72, 0.24, 0.28)	(0.5, 0.19, 0.12)	(0.54, 0.04, 0.26)
(0.75, 0.39, 0.39)	(0.75, 0.2, 0.15)	(0.68, 0.33, 0.26)	(0.53, 0.28, 0.26)
(0.54, 0.38, 0.43)	(0.93, 0.17, 0.41)	(0.54, 0.16, 0.01)	(0.64, 0.12, 0.33)
(0.66, 0.5, 0.39)	(0.87, 0.08, 0.19)	(0.57, 0.11, 0.35)	(0.56, 0.38, 0.35)
(0.61, 0.09, 0.08)	(0.99, 0.17, 0.39)	(0.62, 0.23, 0.33)	(0.67, 0.24, 0.35)
(0.68, 0.02, 0.02)	(0.92, 0.35, 0.12)	(0.53, 0.02, 0.34)	(0.56, 0.32, 0.19)
(0.73, 0.01, 0.37)	(0.86, 0.15, 0.38)	(0.63, 0.41, 0.36)	(0.63, 0.39, 0.17)
(0.62, 0.14, 0.35)	(0.85, 0.41, 0.35)	(0.65, 0.21, 0.1)	(0.67, 0.28 0.36)
(0.68, 0.07, 0.39)	(0.92, 0.29, 0.11)	(0.5, 0.11, 0.09)	(0.76, 0.05, 0.18)
(0.63, 0.48, 0.35)	(0.7, 0.14, 0.08)	(0.62, 0.03, 0.12)	(0.72, 0.02, 0.33)
(0.74, 0.11, 0.4)	(0.79, 0.39, 0.36)	(0.61, 0.26, 0.36)	(0.75, 0.24, 0.31)

Data Analysis

The pre-test and post-test scores were statistically analyzed using techniques such as paired t-tests and ANOVA to determine if the observed differences were significant. Neutrosophic logic was integrated into the analysis to address the indeterminate and neutral aspects of the data, providing a more nuanced understanding of the results.

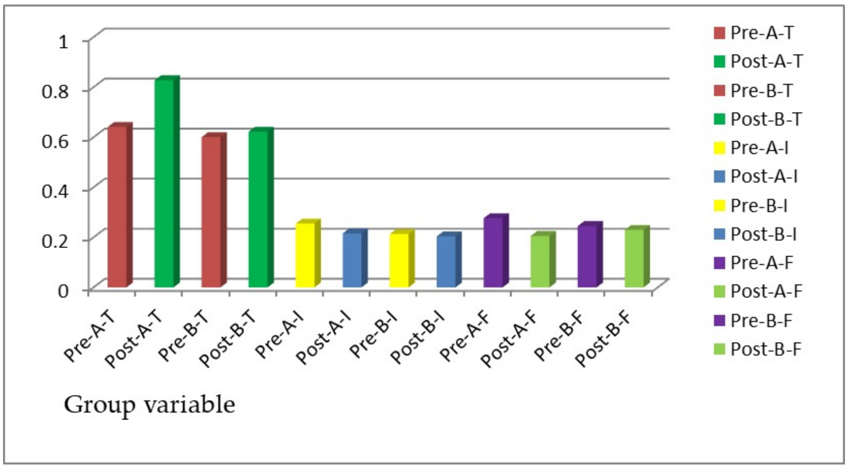

Figure 1: Method Efficiency Relative Mean Comparison

t-Test: Paired Two Sample for Means Group A for True Value		
Mean	0.638055556	0.830556
Variance	0.005713254	0.010205
Observations	36	36
Pearson Correlation	-0.146531248	
Hypothesized Mean Difference	0	
df	35	
t Stat	-8.571696224	
P(T <= t) one-tail	2.03204×10^{-10}	
t Critical one-tail	1.689572458	
P(T <= t) two-tail	4.0464×10^{-10}	
t Critical two-tail	2.030107928	

Table-1: t-Test: Paired Two Sample for Means Group A for True Value
Pearson's correlation (-0.146531248) is a mild negative correlation between the pair of Group -A true values, indicate the weak inverse relation. To test the hypothesis H_0 : there is no significance difference between the mean and H_1 : there is significance difference between the means, extreme small t-statistic (2.03204×10^{-10}) one side indicate a significance difference in mean and extreme small two tailed (4.0464×10^{-10}) conforming statistically significance difference. This suggests mean are not equal in true values of pre and post observation.

t-Test: Paired Two Sample for Means Group B for True Value		
Mean	0.599444	0.623333
Variance	0.004354	0.00636
Observations	36	36
Pearson Correlation	0.078004	
Hypothesized Mean Difference	0	
df	35	
t Stat	-1.44106	
P(T <= t) one-tail	0.079227	
t Critical one-tail	1.689572	
P(T <= t) two-tail	0.158454	
t Critical two-tail	2.030108	

Table-2: t-Test: Paired Two Sample for Means Group B for True Value
Pearson's correlation (0.078004) is a positive correlation between the pair of GroupB true values, indicate the strong positive relation. To test the hypothesis H_0 : there is no significance difference between the mean and H_1 : there is significance difference between the means, positive t -statistic (0.079227) one side indicate no significance difference in mean and small two tailed (0.158454) conforming statistically nonsignificance difference. This suggests mean may equal in true values of pre and post observation.

t-Test: Paired Two Sample for Means Group A for Indeterminacy Value		
Mean	0.254595	0.215676
Variance	0.023998	0.016653
Observations	37	37
Pearson Correlation	-0.08443	
Hypothesized Mean Difference	0	
df	36	
t Stat	1.128247	
P(T <= t) one-tail	0.133339	
t Critical one-tail	1.688298	
P(T <= t) two-tail	0.266679	
t Critical two-tail	2.028094	

Table-3: t-Test: Paired Two Sample for Mean Group A for Indeterminacy Value

Pearson's correlation (-0.08443) is a negative correlation between the pair of Group-A Indeterminacy values, indicate the strong positive relation. To test the hypothesis H_0 : there is no significance difference between the mean and H_1 : there is significance difference between the means, positive *t*-statistic (0.133339) one side indicate no significance difference in mean and small two tailed (0.266679) conforming
statistically significance difference. This suggests mean may equal in Indeterminacy values of pre and post observation.

t-Test: Paired Two Sample for Means Group B for Indeterminacy Value		
Mean	0.208333	0.204167
Variance	0.016671	0.014054
Observations	36	36
Pearson Correlation	0.209153	
Hypothesized Mean Difference	0	
df	35	
t Stat	0.160302	
P(T <= t) one-tail	0.436782	
t Critical one-tail	1.689572	
P(T <= t) two-tail	0.873565	
t Critical two-tail	2.030108	

Table-4: t-Test: Paired Two Sample for Means Group B for Indeterminacy Value

Pearson's correlation (0.209153) is a positive correlation between the pair of GroupB Indeterminacy values, indicate the strong positive relation. To test the hypothesis H_o : there is no significance difference between the mean and H_1 : there is no significance difference between the means, positive *t*-statistic (0.436782) one side indicate a significance difference in mean and small two tailed (0.873565) conforming statistically significance difference. This suggests mean are may equal in Indeterminacy values of pre and post observation.

t-Test: Paired Two Sample for Means Group A for Falsehood Value		
Mean	0.281389	0.208611
Variance	0.017561	0.013201
Observations	36	36
Pearson Correlation	0.061118	
Hypothesized Mean Difference	0	
df	35	
t Stat	2.568599	
P(T <= t) one-tail	0.007317	
t Critical one-tail	1.689572	
P(T <= t) two-tail	0.014635	
t Critical two-tail	2.030108	

Table-5: t-Test: Paired Two Sample for Means Group A for Falsehood Value

Pearson's correlation (0.061118) is a positive correlation between the pairs of Group-A Falsehood values, indicate the strong positive relation. To test the hypothesis
H_0 : there is no significance difference between the mean and H_1 : there is significance difference between the means, positive t-statistic (0.007317) one side indicate a significance difference in mean and small two tailed (0.014635) conforming statistically significance difference. This suggests mean are not equal in Falsehood values of pre and post observation.

t-Test: Paired Two Sample for Means Group B for Falsehood Value		
Mean	0.243611	0.231667
Variance	0.017532	0.010391
Observations	36	36
Pearson Correlation	-0.19372	
Hypothesized Mean Difference	0	
df	35	
t Stat	0.393599	
P(T <= t) one-tail	0.348132	
t Critical one-tail	1.689572	
P(T <= t) two-tail	0.696265	
t Critical two-tail	2.030108	

Table-6: t-Test: Paired Two Sample for Means Group B for Falsehood Value

Pearson's correlation (-0.19372) is a negative correlation between the pair of Group-B Falsehood values, indicate the negative relation. To test the hypothesis H_o : there is no significance difference between the mean and H_1 : there is significance difference between the means, positive t-statistic (0.348132) one side indicate no significance difference in mean and small two tailed (0.696265) conforming statistically significance difference. This suggests mean are may equal in Falsehood values of pre and post observation.

Now, by using the above information we form the following table:

Group	Variable	P- value(Two-tailed)	Conclusion
Group-A	True value	4.0464×10^{-10}	Significance difference
Group-B	True value	0.158454	No - significance difference
Group-A	Indeterminacy value	0.266679	No - significance difference
Group-B	Indeterminacy value	0.873565	No - significance difference
Group-A	Falsehood value	0.014635	Significance difference
Group-B	Falsehood value	0.696265	No - significance difference

Table-7: Summary Findings

From Table-7, it is clearly seen that there is a significance difference in group-A for (True value, Falsehood value) and Group-B are non-significant.

The findings revealed that the experimental group-A showed a significant improvement in mathematical proficiency compared to the control group-B, with paired t-test. Qualitative data from teacher observations and student interviews also indicated that interactive learning environments enhanced student engagement and fostered a more positive attitude toward Mathematics. Neutrosophic analysis highlighted the indeterminate factors influencing these results, offering a comprehensive view of the impact.

4. Discussion

The results support the hypothesis that interactive learning environments can enhance students' mathematical proficiency. Digital tools and collaborative projects appear to facilitate a deeper understanding of mathematical concepts and improve problem-solving skills. These findings are consistent with previous research on the benefits of interactive learning in other disciplines. The study also underscores the potential of technology to make math instruction more accessible and engaging. By providing personalized learning experiences, interactive platforms can address the diverse needs of students, helping them overcome challenges and reach their full potential. Neutrosophic sets provided valuable insights into the uncertainties and neutralities inherent in the educational process, enriching the overall analysis.

5. Conclusion

This study highlights the importance of adopting innovative teaching strategies to improve math instruction. The management of interactive learning environments plays a crucial role in enhancing mathematical proficiency among students. By employing a neutrosophic framework to address uncertainties and indeterminacies, this study has demonstrated the significant potential of integrating and managing educational technologies and collaborative teaching methods. Traditional learning settings often fall short in catering to the diverse cognitive and emotional needs of students, leading to disengagement and suboptimal mathematical performance. However, through the strategic management of interactive learning tools such as educational software, gamified platforms, and virtual manipulatives, educators can create a more inclusive and effective mathematical learning experience.

Through the lens of neutrosophic sets, which account for indeterminacies and neutralities in the learning process, it becomes evident that these environments can address the diverse needs of students and enhance their mathematical proficiency. For more works on this field one may go through the works of [3], [4], [5]. The neutrosophic applications provide a comprehensive and innovative framework for addressing reallife challenges, bridging the gap between mathematical reasoning and social sciences. This interdisciplinary approach enables a deeper understanding of uncertainty, indeterminacy, and inconsistency in complex systems. For those interested in exploring advanced extensions of Neutrosophic theory, the pioneering works of Prof. F. Smarandache [8] serve as a valuable resource, offering profound insights into its theoretical foundations and practical implementations.

Future research should focus on investigating the long-term effects of these approaches and their applicability across various educational contexts. By considering the indeterminate factors and uncertainties inherent in educational settings, further
studies can provide a more comprehensive understanding of how interactive learning environments can be optimized to achieve the best outcomes for students.

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