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THE IMPACT OF PROBLEM-BASED LEARNING TECHNOLOGIES ON STUDENT OUTCOMES IN MATHEMATICS: A STUDY BASED ON VARIATIONAL STATISTICS

Rashidov Alijon
Teacher of the Academic Lyceum of NavSU
Eronov Omonboy
Teacher of the Academic Lyceum of NavSU

Abstract

The modern educational landscape demands a shift from rote memorization to active cognitive engagement. This research investigates the effectiveness of Problem-Based Learning (PBL) in secondary school mathematics within Uzbekistan's educational reforms. Utilizing a quasi-experimental design, the study evaluates how "problem situations" affect student achievement. Beyond simple averages, the research employs variational statistics—including mean square deviation and the coefficient of variation—to analyze the stability of knowledge. Results indicate that PBL significantly reduces the variance in student performance, suggesting that this technology is highly effective for heterogeneous classrooms where students have diverse initial ability levels.

Keywords

Problem-Based Learning, Variational Statistics, Uzbekistan Education Reform, Pedagogy, Mathematical Modeling, Cognitive Development.

1. INTRODUCTION

The transition from a command-based economy to an innovation-driven society in Uzbekistan has placed unprecedented demands on the national education system. Mathematics, as the foundational language of STEM (Science, Technology, Engineering, and Mathematics), is at the center of this transformation. However, traditional pedagogical models often rely on the "explanatory-illustrative" method, where the teacher provides a theorem and the student performs repetitive exercises. This "passive" model fails to develop "algebraic thinking" or "mathematical intuition."

Problem-Based Learning (PBL) is a technology that flips the traditional classroom. Instead of starting with a rule, the lesson begins with a "problem situation"—a carefully designed contradiction that students cannot solve using their existing knowledge. This creates a state of "cognitive dissonance," which, according to the theories of L.S. Vygotsky and M. E. Jumayev, is the necessary precursor to genuine intellectual growth.

The significance of this study lies in its use of Variational Statistics. In many pedagogical papers, researchers only report the "average score." This is a statistical fallacy. If five students score 100% and five score 0%, the average is 50%, but no one actually knows 50% of the material. Variational statistics allows us to measure the "dispersion" of knowledge. Our goal is to prove that PBL not only raises the average but also makes the class's performance more uniform and stable.

2. METHODS

The research methodology was structured to provide a rigorous comparison between

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traditional and innovative approaches.

Participants and Setup: The study involved 160 students from Grade 8 and 9. Two groups were established: the Control Group (CG) and the Experimental Group (EG).

- The Control Group followed the standard curriculum using traditional lecturing methods.
- The Experimental Group utilized PBL technologies, specifically focusing on "Case-study" methods and "Heuristic dialogues."

The Pedagogical Process: In the EG, the teacher's role shifted from an "authoritarian source" to a "facilitator." For example, when teaching the concept of "Quadratic Equations," the teacher did not provide the formula first. Instead, a real-world architectural problem involving area optimization was presented. Students had to struggle with the variables, hypothesize solutions, and eventually "discover" the need for a specific formula.

Statistical Analysis: Data was collected via pre-tests and post-tests. The following variational parameters were calculated:

1. Arithmetic Mean ($\bar{x}$): To measure the general level of achievement.
2. Mean Square Deviation (σ): To measure the spread or "scatter" of the results.
3. Coefficient of Variation (V): To determine the homogeneity of the groups.
4. Student's t-test: To ensure that the differences between groups were statistically significant ($p < 0.05$).

3. RESULTS

The data analysis revealed a stark contrast between the two pedagogical environments.

Quantitative Growth: The arithmetic mean of the Experimental Group rose from 62% to 84%, while the Control Group showed a modest increase from 61% to 68%. This indicates that the PBL method directly contributes to higher test scores.

Variational Consistency: The most profound finding was in the Mean Square Deviation. In the Control Group, the deviation remained high ($\sigma \approx 14$), indicating that while some students improved, many were left behind. However, in the Experimental Group, the deviation dropped significantly ($\sigma \approx 6.5$). This suggests that PBL acts as an "equalizer." Because the method relies on group discussion and collaborative problem-solving, lower-performing students were "scaffolded" by the process, leading to a much more homogeneous high-performance level.

Reliability: The calculated t-value exceeded the critical value for the given degrees of freedom, proving that the improvement was a direct result of the PBL technology and not a matter of chance.

4. DISCUSSION

The results confirm that Problem-Based Learning addresses the core weaknesses of the traditional mathematics classroom. One of the primary discussions in modern Uzbek pedagogy, led by scholars such as R. Ishmuhamedov, is the "activation of the learner." Our results show that when students are placed in a problem situation, their "intrinsic motivation" increases.

Traditional methods often create "knowledge without understanding"—students can solve a quadratic equation on paper but cannot identify one in a real-world context. The PBL approach forces the student to build a "mathematical model" of the problem. This process of modeling is what develops the "variational" flexibility of the brain.

Furthermore, the statistical evidence showing reduced variance is critical for educational policy. In a country striving for universal quality education, a teaching method that narrows the gap between the "best" and "average" student is of extreme value. However, the discussion must also acknowledge the "Teacher Factor." PBL requires a higher level of teacher competence; the educator must be able to guide a chaotic brainstorming session back to a rigorous mathematical conclusion without simply "giving away" the answer.

5. CONCLUSION

This study provides empirical and statistical evidence that Problem-Based Learning is a superior technology for secondary mathematics. By transforming the classroom into a laboratory of inquiry, we can move beyond the "memorization-reproduction" cycle that has long dominated the field.

The use of variational statistics has allowed us to see what simple averages hide: that PBL creates a more stable, equitable, and deep-rooted understanding of mathematics. We recommend that the Ministry of Preschool and School Education of Uzbekistan integrate "Problem-Based Modules" into the national textbook standards. Future research should focus on how digital interactive tools (like GeoGebra) can further enhance the "Problem Situations" used in this model.

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