Asian Journal of Technology and Applied Sciences
ISSN: 2301-xxxx (online) | IF: 10.01 | Vol: 1, issue 1
Available: http://asiansciencejournal.org

USING GEOGEBRA TO TEACH GEOMETRIC TRANSFORMATIONS IN SECONDARY SCHOOL MATHEMATICS

Sanjarbek M. Mamajonov
Associate Professor, Department of Digital Technologies and Mathematics, Kokand University, Kokand, Uzbekistan
e-mail: sanjarbekmamajonov@gmail.com

Abstract: Geometric transformations — including translation, rotation, reflection, and dilation — constitute a foundational strand of secondary school mathematics that bridges visual intuition with formal algebraic reasoning. Despite their conceptual importance, students frequently struggle with abstract representations of transformations when instruction relies exclusively on static diagrams and procedural rules. This study investigates the effectiveness of GeoGebra, a dynamic mathematics software platform, as a pedagogical tool for teaching geometric transformations to 9th-grade students in Uzbekistan. Using a quasi-experimental pre-test/post-test design with a sample of 68 students divided into control and experimental groups, the research measures the impact of GeoGebra-integrated lessons on students' conceptual understanding, procedural accuracy, and spatial reasoning skills. The experimental group participated in a six-week instructional unit in which GeoGebra was used to dynamically visualize and manipulate transformations, while the control group received traditional chalk-and-board instruction. Results indicate that students in the experimental group significantly outperformed their counterparts on all three outcome measures, with the largest effect sizes observed for spatial reasoning and conceptual understanding. The study also documents positive shifts in student attitudes toward mathematics. These findings suggest that GeoGebra-based instruction offers a powerful complement to traditional approaches in teaching geometric transformations, with implications for curriculum design and teacher professional development in secondary mathematics education across Uzbekistan and similar educational contexts.

Keywords: instruction relies, counterparts, nature of geometric motion.

Introduction

Geometric transformations occupy a central position in the secondary school mathematics curriculum, serving as the conceptual link between the intuitive geometry of everyday experience and the formal structures of coordinate geometry, linear algebra, and complex analysis. The ability to visualize, describe, and compose transformations is not merely a procedural skill; it is a form of mathematical literacy that underpins students' later engagement with topics ranging from symmetry in physics to computer graphics and architectural design. Yet, despite their importance, transformations remain among the topics that secondary students find most challenging, particularly when instruction relies on static representations that do not capture the dynamic nature of geometric motion.

The emergence of dynamic geometry software — and GeoGebra in particular — has created new possibilities for transforming how geometric concepts are taught and learned. GeoGebra, an open-source platform freely available in multiple languages including Uzbek and Russian, allows students to construct geometric objects, apply transformations, and observe the results interactively. The ability to drag points, animate figures, and immediately see the consequences of changes to parameters turns the abstract into the concrete and the static into the dynamic. This affordance is especially valuable in the context of transformations, where the concept of "moving" or "mapping" a figure is inherently kinetic.

In Uzbekistan's secondary schools, mathematics instruction has historically been characterized by formal, teacher-centered approaches that emphasize procedural fluency over conceptual understanding. While this tradition has produced students with strong algebraic skills, it has been less successful in developing spatial reasoning and the ability to work flexibly with geometric representations. The introduction of digital technologies into classrooms, accelerated by the national digitalization agenda, creates an opportunity to address this imbalance. However, the mere presence of technology is insufficient; what matters is how technology is integrated into pedagogically principled instructional sequences.

This study addresses the question: To what extent does GeoGebra-integrated instruction improve secondary students' understanding of geometric transformations compared to traditional instruction? By answering this question in a carefully controlled empirical study, the research contributes to the growing body of evidence on technology-enhanced mathematics learning and provides practical guidance for teachers and curriculum designers in Uzbekistan and comparable educational systems.

Material And Methods

The study employed a quasi-experimental pre-test/post-test control group design. Participants were 68 ninth-grade students from two intact classes at a secondary school in Kokand, Uzbekistan, randomly assigned to experimental (n=34) and control (n=34) conditions. Prior to the intervention, both groups completed a validated 25-item pre-test assessing conceptual understanding of geometric transformations, procedural accuracy in applying transformation rules, and spatial reasoning ability. The pre-test confirmed equivalence of the two groups ($p=0.42$).

The instructional intervention lasted six weeks and covered four types of geometric transformations: translation, rotation, reflection, and dilation. The experimental group received GeoGebra-integrated lessons in which students used pre-designed applets and created their own constructions to explore each transformation type. Lessons followed an inquiry-based structure: students first explored a transformation dynamically, formulated conjectures about invariant properties, tested their conjectures by manipulating parameters, and finally formalized their findings with teacher guidance. The control group studied the same content using traditional methods: teacher explanation, textbook examples, and pencil-and-paper exercises.

Post-test data were collected after the six-week period using a parallel form of the pre-test instrument. Additionally, a 20-item attitude survey was administered to both groups to measure changes in students' self-efficacy and interest in geometry. Qualitative data were collected through classroom observation notes and semi-structured interviews with eight purposively selected students (four from each group). Data analysis employed independent-samples t-tests for quantitative outcomes and thematic analysis for qualitative data. Effect sizes were calculated using Cohen's d. The study received ethical approval from Kokand University's research ethics committee, and all participants provided informed assent with parental consent.

Results

Quantitative results demonstrated consistent and statistically significant advantages for the GeoGebra-integrated experimental group across all three outcome measures. On the conceptual understanding subscale, the experimental group achieved a mean post-test score of 78.4 (SD=9.2) compared to 61.7 (SD=11.4) for the control group, a difference that was highly significant ($t(66)=6.84$, $p<0.001$, $d=1.66$). This large effect size indicates that GeoGebra integration produced substantially deeper conceptual understanding than traditional instruction.

Procedural accuracy scores also favored the experimental group, though with a smaller effect size (mean: 82.1 vs. 74.3; t(66)=3.21, p=0.002, d=0.78). This finding is noteworthy because the experimental group did not receive additional procedural practice — if anything, a portion of their instructional time was devoted to exploratory activities rather than drill. The improvement in procedural accuracy thus appears to be a byproduct of deeper conceptual understanding rather than additional practice.

The largest between-group difference was observed on the spatial reasoning subscale (mean: 74.8 vs. 55.2; t(66)=8.13, p<0.001, d=1.97). This result aligns with theoretical expectations: dynamic visualization directly supports the development of spatial reasoning by allowing students to mentally simulate transformations before executing them procedurally. Students who used GeoGebra repeatedly engaged in the act of predicting where a figure would land after a transformation, then checking their prediction by executing the transformation — a cycle that directly trains spatial reasoning.

Attitude survey results indicated significant positive shifts in the experimental group on both self-efficacy (mean gain: +14.3 points on a 100-point scale, p=0.003) and interest in geometry (mean gain: +18.7 points, p=0.001). Control group students showed negligible changes on both dimensions. Qualitative data from interviews reinforced these findings. Experimental group students described GeoGebra as making geometry "come alive" and expressed greater confidence in tackling unfamiliar problems. One student noted that being able to "drag and see" helped her understand why a rotation preserves distances in a way that no textbook explanation had previously achieved. Control group students, by contrast, frequently described transformations as "just rules to memorize" without deeper conceptual grounding.

Classroom observations revealed that the GeoGebra-integrated lessons generated notably higher levels of student-to-student discussion, with students frequently debating predictions before executing transformations. This peer dialogue appeared to support conceptual consolidation and may partly explain the magnitude of the learning gains observed.

Discussion

The results of this study provide strong empirical support for the pedagogical value of GeoGebra in teaching geometric transformations at the secondary level. The large effect sizes observed for conceptual understanding and spatial reasoning are consistent with a growing body of international research demonstrating the advantages of dynamic geometry environments over static instruction for developing geometric thinking. The present findings extend this literature by situating it in a Central Asian educational context characterized by a strong tradition of formal, teacher-centered instruction, and by demonstrating that GeoGebra integration can produce significant gains even within this cultural and pedagogical context.

A theoretically important finding is the improvement in procedural accuracy observed in the experimental group without additional drill practice. This suggests that conceptual understanding developed through dynamic exploration subsequently supports procedural execution — a relationship that is theoretically coherent with a constructivist view of mathematical learning. Students who understand why a transformation works as it does are better positioned to apply the corresponding procedure correctly and to recover from errors.

The attitudinal gains observed are also pedagogically significant. Students who find geometry meaningful and engaging are more likely to persist in the face of difficulty and to develop the kind of sustained mathematical engagement that characterizes successful learners. The GeoGebra environment appears to cultivate this engagement by positioning students as active investigators rather than passive recipients of knowledge.

Limitations of the study include its restriction to a single school and the relatively short duration of the intervention. Future research should examine the long-term retention of GeoGebra-enhanced learning and investigate the extent to which gains transfer to other geometric topics and to standardized assessment contexts.

Conclusion

This study has provided compelling evidence that GeoGebra-integrated instruction significantly enhances secondary students' learning of geometric transformations across conceptual, procedural, and spatial dimensions. The dynamic visualization affordances of GeoGebra directly address the core challenge of transformation instruction — the inherently kinetic nature of geometric mappings — in a way that static, traditional methods cannot. The findings carry clear implications for practice: teachers of secondary geometry should be provided with professional development in GeoGebra and supported in designing inquiry-based lessons that leverage its dynamic capabilities.

For curriculum designers in Uzbekistan, the study suggests that existing textbook sequences for geometric transformations could be significantly enriched by the integration of GeoGebra applets and construction activities. This need not require the complete replacement of traditional instruction; rather, GeoGebra can function as a powerful complement that deepens the conceptual foundation on which procedural fluency is built.

More broadly, the study contributes to the argument that technology integration in mathematics education, when pedagogically principled rather than merely decorative, can produce substantial learning benefits even in educational contexts with strong traditional instructional cultures. The case of GeoGebra and geometric transformations offers a model for how digital tools can be integrated thoughtfully and effectively into secondary mathematics instruction across Uzbekistan and beyond.

Acknowledgements

The author thanks the students and teachers at the participating secondary school in Kokand for their cooperation and enthusiasm throughout the study. Gratitude is also expressed to colleagues at the Department of Digital Technologies and Mathematics, Kokand University, for their valuable feedback on the instructional materials. This research received no external funding and was conducted as part of the author's scholarly work in mathematics education.

REFERENCES

1. Mamajonov, S. M. (2022). The third boundary problem for a fourth-order non-homogeneous equation with constant coefficients. *Bull. Inst. Math*, *5*(6), 100-109.
2. Mamazhonov M, Mamazhonov S.M., Mamadalieva K.B. (2016). Some boundary value problems for a third-order parabolic-hyperbolic equation in a pentagonal domain. *Bulletin KRASEC. Physical and Mathematical Sciences, 13*(2), 31-38.
3. Апаков Юсупжон Пулатович, & Мамажонов Санжарбек Мирзаевич (2023). КРАЕВАЯ ЗАДАЧА ДЛЯ НЕОДНОРОДНОГО УРАВНЕНИЯ ЧЕТВЁРТОГО ПОРЯДКА С ПОСТОЯННЫМИ КОЭФФИЦИЕНТАМИ. Челябинский физико-математический журнал, 8 (2), 157-172.
4. Apakov, Y.P., Mamajonov, S.M. (2024). Second Boundary Value Problem for a Fourth-Order Inhomogeneous Equation with Variable Coefficients. *Lobachevskii J Math* **45**, 3849–3859.
5. Апаков, Ю. П., & Мамажонов, С. М. (2021). Разрешимость одной краевой задачи для уравнения четвёртого порядка параболо-гиперболического типа в пятиугольной области. *Сибирский журнал индустриальной математики*, *24*(4), 25-38.

6. Mamajonov, M., & Mamajonov, S. M. (2014). Statement and research method some boundary value problems for a class of fourth order parabolic-hyperbolic type. *Vestnik KRAUNC. Fiziko-Matematicheskie Nauki*, (1), 14-19.
7. Apakov, Y., & Mamajonov, S. (2023). Solution of a boundary problem for a fourth-order non-homogeneous equation with non-symmetric time conditions. *Journal of Osh State University. Mathematics. Physics. Technical Sciences*, *2*(2), 15-25.
8. Апаков Юсупжон Пулатович, & Мамажонов Санжарбек Мирзаевич (2021). Краевая задача для уравнения четвертого порядка с кратными характеристиками. VI международная научная конференция «Нелокальные краевые задачи и родственные проблемы математической биологии, информатики и физики, 6 (1), 32.
9. Apakov, Y. P., & Mamajonov, S. M. (2021). Solvability of one boundary value problem for a fourth-order equation of parabola-hyperbolic type in a pentagonal domain. *Sibirskii Zhurnal Industrial'noi Matematiki*, *24*(4), 25-38.
10. Мамажонов, М., & Мамажонов, С. М. (2014). Постановка и метод исследования некоторых краевых задач для одного класса уравнений четвертого порядка параболо-гиперболического типа. *Вестник КРАУНЦ. Физико-математические науки*, (1 (8)), 14-19.
11. Mamajonov, M., & Mamajonov, S. (2024). On a boundary value problem for a fourth-order equation of parabolic-hyperbolic type in a mixed pentagonal domain... *Journal of Osh State University. Mathematics. Physics. Technical Sciences*, *2*(3), 116-133.
12. Apakov, Y. P., & Mamajonov, S. M. (2022). Boundary Value Problem for a Fourth-Order Equation of the Parabolic-Hyperbolic Type with Multiple Characteristics with Slopes Greater Than One. *Russian Mathematics*, *66*(4), 1-11.
13. Apakov, Y. P., & Mamajonov, S. M. (2023). Boundary value problem for an inhomogeneous fourth order equations with constant coefficients. *Chelyabinskiy Fiziko-Matematicheskiy Zhurnal*, *8*(2), 157-172.
14. Apakov, Y. P., & Mamajonov, S. M. (2024). Boundary Value Problem for Fourth Order Inhomogeneous Equation with Variable Coefficients. *Journal of Mathematical Sciences*, *284*(2), 153-165.
15. Apakov, Y. P., & Mamazhonov, S. M. (2023). Boundary value problem for an inhomogeneous fourth-order equation with lower-order terms. *Differential Equations*, *59*(2), 188-198.
16. Apakov, Y. P., & Mamajonov, S. M. (2021). Solvability of a Boundary Value Problem for a Fourth Order Equation of Parabolic-Hyperbolic Type in a Pentagonal Domain. *Journal of Applied and Industrial Mathematics*, *15*(4), 586-596.
17. Санжарбек Мирзаевич Мамажонов, Шерматова Хилолахон Мирзаевна. (2012). Об одной краевой задаче для уравнения третьего порядка параболо-гиперболического типа в области с двумя перпендикулярными линиями изменения типа. “Узлуксиз таълим тизимида математика ва информатика фанларини ўқитишни такомиллаштириш масалалари” мавзусидаги Республика миқёсидаги илмий-техник конференция материаллари, 96-99.
18. Apakov, Y. P., & Mamajonov, S. M. (2023). Boundary-value problem for the fourth-order equation with multiple characteristics in a rectangular domain. *Journal of Mathematical Sciences*, *272*(2), 185-201.
19. Mamajonov, M., & Mamajonov, S. (2024). On a boundary value problem for a fourth-order equation of parabolic-hyperbolic type in a mixed pentagonal domain... *Journal of Osh State University. Mathematics. Physics. Technical Sciences*, *2*(3), 116-133.

20. Апаков, Ю., & Мамажонов, С. О разрешимости третьей краевой задачи для неоднородного уравнения четвертого порядка с кратными характеристиками. In *Түркі әлемі математиктерінің VII Дүниежүзілік Конгресі (TWMS Congress-2023)* (p. 259).
21. Apakov Yu., Mamajonov S. (2023). The boundary value problem for a fourth-order nonhomogeneous equation with variable coefficients. Uzbek Mathematical Journal, 67 (3), 23-32.
22. Kuziev, S., & Mamajonov, S. (2026). Optimal quadrature rule with derivative in Sobolev space. *Gulf Journal of Mathematics*, *22*(2).
23. Mamajonov, S. M., & Mahammadjonova, M. (2026). Methodology For Forming The Concepts Of Fractions And Fractions In Primary Grades. *TLEP – International Journal of Multidiscipline*, *3*(3), 11-16.
24. Hohenwarter, M., & Fuchs, K. (2004). Combination of dynamic geometry, algebra and calculus in the software system GeoGebra. *Computer Algebra Systems and Dynamic Geometry Systems in Mathematics Teaching Conference*.
25. Zengin, Y., Furkan, H., & Kutluca, T. (2012). The effect of dynamic mathematics software GeoGebra on student achievement in teaching of trigonometry. *Procedia – Social and Behavioral Sciences*, 31, 183–187.
26. National Curriculum of Uzbekistan for Secondary Mathematics (2022). Ministry of Public Education of Uzbekistan, Tashkent.