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Effect of Geogebra Software on Students' Academic Performance in Mensuration at the Senior High School Level

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Abstract:- This study investigated the effects of GeoGebra software on students' academic performance in mensuration at the Senior High School level. The study employed a quantitative research method which adopted a quasi-experimental research design with pretest-posttest non-equivalent control groups. Test and questionnaire were used to collect data for the study and the collected data was analysed using descriptive statistics and an independent sample t-test. Two intact classes comprising 60 second-year Senior High School students of the Upper East Region were used for both control and experimental groups. The independent t-test analysis revealed a significant difference in the posttest mean scores between the control and experimental groups. Again, the descriptive statistics of the questionnaire showed positive feedback from students towards incorporating GeoGebra software in the teaching and learning of Mensuration. The study, therefore, recommended that the use of GeoGebra should be made to form an integral part of the Senior High School Curriculum and teachers should be trained on how to use it. Also, Teachers should incorporate GeoGebra in teaching mathematics in Senior High Schools since it has positive effects on students' academic performance.

Keywords:- *GeoGebra software, Traditional Method, Students' Academic Performance, Students' Perception.*

I. INTRODUCTION

Mathematics is one of the major subjects considered throughout Ghanaian Educational levels. The field of social sciences helps us to be able to decode the environment and find solutions to problems in the world, be they social, scientific, or economic (Wilson, 2018). It opens up the understanding of people to various phenomena and fields of study, which can be social, economic, or historical facts (Carvajalino, 2018). Hence it has become an adequate tool and skill to acquire knowledge and present facts from the environment. It is a subject that is learned by all pre-tertiary institutions in Ghana. According to Bassey (2020), mathematics is a foundation for global and national growth, mathematics is essential for understanding and using science and technology. Mathematics is important for both literate and illiterate members of society because of its applications in daily life, including transportation, business of all kinds, and contributions to scientific and technological advancement. (Golji & Damgpe, 2016).

Mathematics is one of the subjects considered a prerequisite for admission into tertiary institutions and state agencies in Ghana. One cannot be admitted without a pass in mathematics. Despite this, research has shown that mathematics is one of the challenging subjects and the majority of students in Ghana have difficulties understanding different concepts in the subject most especially geometry (Mensah-Wonkyi & Adu, 2016). For this reason, various educational stakeholders and curriculum developers are looking for ways to learn mathematics,

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especially the basic Schools and Senior High Schools for students to have a good foundation in the subject.

Geometry, one of the oldest branches of mathematics originates from two Greek words, “Earth and Measuring” which means earth measurement. The first country to have civilization in geometry is the Egyptians. It was developed partly for re-establishing landmarks and boundaries after the Nile floods. Geometry helps represent and resolve issues in other branches of mathematics in practical contexts and instils in students’ fundamental abilities like analysis, comparison, and generation. Euclidean geometry is the name given to the earliest type of geometry (named after Euclid, the famous Greek mathematician). The development of Lobachevsky’s geometry later added to the plane geometry of Euclidean geometry to create the foundation for modern solid geometry (Bonola, 1995). Right from its onsets, students had always found geometry uninteresting. Even famous Pythagoras found it difficult to get a willing student in Geometry (Maor, 2019). The pre-tertiary mathematics curriculum (CRDD, 2010) outlines the mathematics syllabus into seven primary sections of which geometry had four. The four major themes deal with the relations and qualities of lines, points, planes and solid figures, making them an important component in the field of mathematics.

The whole world and its activities are full of geometrical applications, it makes one understand the world (Schopenhaur, 2016). Architectural, engineering works, etc. are all integral aspects of Geometry; hence it is obvious that the world cannot do anything without geometry. “Without the world, geometry does not exist and without geometry, the world does not exist”. According to Serin (2018), our life is full of Geometrical shapes. Therefore, geometry is recommended for all basic and pre-tertiary education. The purpose of teaching geometry is to assist students in seeing forms and flat figures that may not be readily seen and understood (Clements, & Saarama, 2022). Many students do not like the area of mensuration when it comes to topics in mathematics. Countries over the world are putting more effort into finding new and effective ways of teaching geometry to promote academic achievement and students’ interest to learn. In other to make mathematics lessons interesting, learning must be integrated with ICT since technology is one of the most effective tools that influence students’ participation in learning in today’s era. The twenty-first-century students are well equipped with various mobile phone apps due to their constant usage of mobile phones, and other electronic gadgets.

GeoGebra is one of the software developed by two graduate students (Marcus Hohenwater & Yves Keris) in 2001. The software was developed to aid mathematics lessons at the basic and Senior High School levels and college of education (Hohenwater & Preiner, 2007). GeoGebra is a package with much interactive geometry software for mathematics lessons (Dahal, Shrestha & Pant 2019). According to Bhagat and Chang (2015), the integration of ICT into mathematics lessons tends motivating students at the same levels. Thereby leading to good performance in their academics. GeoGebra is an accessible and dynamic mathematics software that combines geometry, algebra, and calculus into a single, approachable tool (Hohenwater, Jarvis, & Lavicza, 2008). Features from prior versions of Geometer’s Sketchpad, Maple, Derive, and Cabri were included in this program (Sahaa, Ayub, & Tarmizi, 2010). The free and user-friendly application of GeoGebra software enables us to connect geometry with algebra (Wallace, Clark & White, 2012). The support resources for GeoGebra software are really good (Particularly for a free tool). With user-contributed additions, these resources are extremely succinct, readily available, and expertly produced. According to the GeoGebra website, this collaborative learning environment emphasizes "quality against quantity" (Grandgenett, 2007).

II. PROBLEM STATEMENT

Geometry has been of special interest to all stakeholders of education in Ghana. Much research has revealed that mathematics is abstract, especially shapes and diagrams (Idris, 2010). According to Idris (2010), students do not see the essence of geometry because educators have failed to develop a visualization of geometrical concepts in learning. Many students move out of class when it is time for mathematics such as Mensuration and other related Geometry topics. While the teacher provides the necessary information (Charts and Carboards demonstration) to let students understand the ideas of mensuration, students appear to have difficulty applying this knowledge to a given activity. It seems as though additional guidance is needed to help students manipulate geometry properties for them to completely comprehend and visualize geometry properties. This perspective is reinforced by the studies (Battista, 1999; Prescott, Mitchelmore & White, 2002) which show that students struggle to understand the ideas and necessary information when learning geometry.

The teaching of geometry has been of great concern to mathematicians and educational stakeholders (Mesa, Gomez, & Cheah, 2012). A research report presented by Mji and Makgato (2006) revealed that there is a critical issue regarding teaching and learning mathematics in South Africa. Also, the Chief examiners’ reports for the past eight years (2015 to 2022) revealed that students performed abysmally poorly in the area of geometry (West Africa Secondary School Examination). It has frequently been observed in Bongo District that, students still struggle to understand mensuration when it is taught and learned. It seems as though additional guidance is needed to help students explore geometry properties for them to completely comprehend and visualize geometry properties. These challenges students faced in geometry could be attributed to a lack of visualization of geometrical properties during the teaching and learning of geometry. Hence there is a need for innovative methods of teaching geometry. One such innovative way is the use of GeoGebra software. Though the GeoGebra software has been in existence for a very long time little is seen of its effects on students’ academic performance in geometry in the Upper East Region of Ghana. This study, therefore, examines the effects and the

perceptions of GeoGebra software on students' academic performance in Geometry.

➢ *Research Objectives*

This study sought to find out how well students' understanding of Mensuration improved after using GeoGebra and also elicit students' perceptions of GeoGebra software in the Bongo Senior High School in the Upper East Region of Ghana. The specific objectives sought to:

- determine whether there is a difference between the posttest mean scores of students taught using the GeoGebra software and those taught without the use of the GeoGebra software.
- determine students' perception of the GeoGebra software during the teaching and learning of mensuration.

➢ *Research Hypotheses*

- there is no significant difference between the posttest mean scores of students taught using GeoGebra and students taught without GeoGebra.

➢ *Research Question*

- What is students' perception of GeoGebra software as a technological tool in the teaching and learning of Mensuration?

III. LITERATURE REVIEW

Research conducted by Krueger and Kumar (2004), has revealed that in some countries ICT has been integrated into the educational structure and method of teaching. The Ministry of Education and Vocational Training (MoEVT) of Tanzania introduced ICT in the year 2002, as a teaching tool, not just as a subject to be taught but also should be integrated as a teaching pedagogy in learning mathematics and science (Kayyulilo & Voogt, 2015).

According to one study, GeoGebra can assist students in understanding experimental, problem-based, and research-based mathematics learning both in the classroom and at home (Dikovi, 2009,). Students can benefit from this program by being able to "understand the principles buried in technology" (Pandiscio 2002). In another study, geometry teaching improved students' learning outcomes (Saha, Ayub, & Tarmizi, 2010). The coordinate system's geometry. Other research employed GeoGebra and found that there were substantial variations in the scores of the two groups (control and experimental). (Shadaan & Eu, 2013; Zengin, Furkan, & Kutluca, 2012). In these conditions, the experimental group outperformed the control group in a big way." According to Guven (2012), the experimental group outperformed the control group in terms of academic accomplishment as well as levels of learning of transformation geometry when GeoGebra was used as a teaching tool. GeoGebra is an example of dynamic software that benefits student learning and achievement. Additionally, it has been seen to have a good impact on students (Dogan & Içel, 2011). An open-source program for studying mathematics is called GeoGebra. GeoGebra validates various dynamic representations' constituent parts and offers a wide range of computational tools for modelling and simulation. Numerous mathematical materials are accessible to people all around the world with GeoGebra's user-friendly interface and web platform. Below is the GeoGebra software for learning the various topics of mathematics.

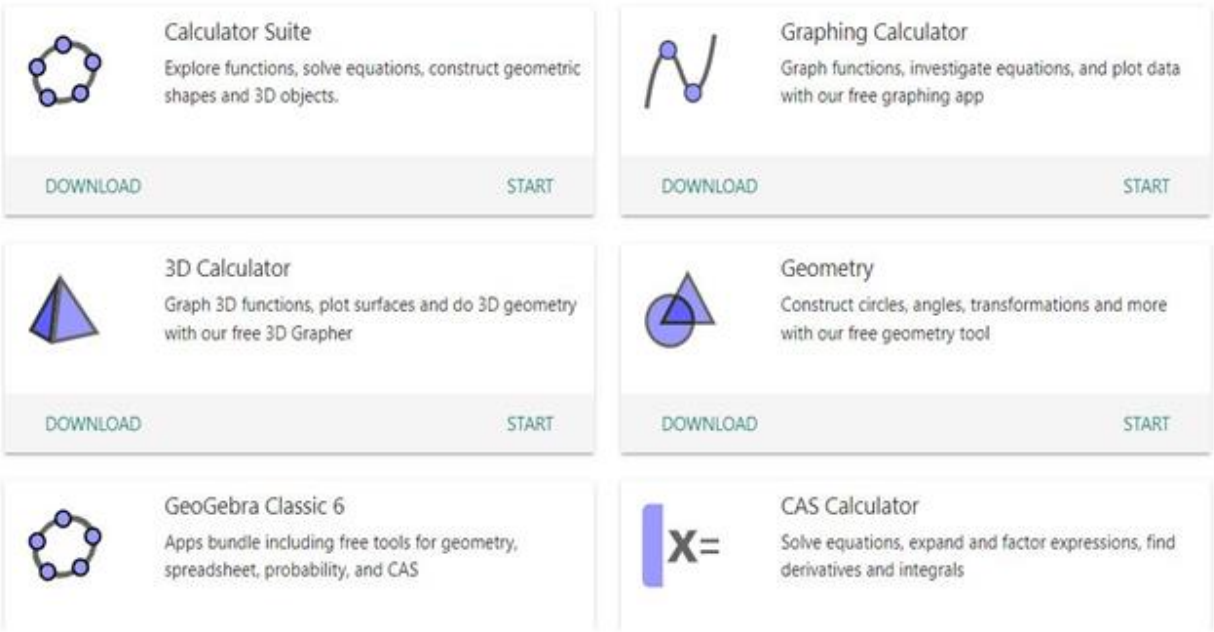

Fig 2 shows various GeoGebra Software

Figure 2 above depicts the six kinds of GeoGebra software. To study functions, solve equations, create geometry shapes, and create three-dimensional objects, one uses a calculator suite: Calculator for graphing, which is also used to examine graph equations and plot data. The GeoGebra 3D calculator provides a visual representation of 3D graphing operations and is used to determine the surface area of 3D objects. The construction of circles, angles, transformations, and other objects all involve geometry. Finally, the CAS calculator is used to solve equations, expand and factorize equations, and calculate the derivatives and integrals of functions. GeoGebra Classic 6 is utilized for geometry worksheets and probability.

Numerous studies have shown that GeoGebra can be utilized to raise student achievement. These studies included one by Saha et al (2010). "The main objective was to determine how utilizing GeoGebra to teach Coordinate Geometry affected students' performance. 53 secondary school students participated in the study and were divided into two groups: the control group and the experimental group. While the control group did not utilize the software, the experimental group received instruction using GeoGebra. The outcome was that the experimental group outperformed the control group by a large margin. The implication was that the use of GeoGebra in blended instruction was a valuable addition to the traditional approach to teaching mathematics. The research tool for the study was an accomplishment test. "The sample was divided into two groups: the experimental group (17 students), who received instruction using the software, and the control group (15 students), who received instruction at an elementary school for 11 hours without using the software. The study's conclusions showed that the experimental group and the control group differed significantly from one another. This result shows that using GeoGebra helped the students who use the software with a great outcome score than the traditional instruction students. Additionally, it showed that the students who used the software recalled information better than the kids who learned in a computer-free environment and learned more efficiently using GeoGebra. Selçik and Bilgici's (2011) findings were comparable to Zengin, Furkan, and Kutlucaa's (2012) study. The goal of Zengin et al (2012), study was to ascertain GeoGebra's impact on students' trigonometry performance. According to Zengina, et al. (2012) findings, GeoGebra raised learners' proficiency more effectively than the students who were taught using the conventional method. The usage of GeoGebra in mathematics lessons was cited as a successful constructivist instructional technique by Zengina, et al. (2012).

A study by Shadaan and Leong (2013) sought to determine how GeoGebra affected students' comprehension of the teaching and learning of circles. Ninety-five students were divided into the treatment group and the control group for the study. Pre- and post-tests were used in the study to evaluate the impact of GeoGebra on students' performance in learning circles. The study's results revealed that pupils who used GeoGebra to learn about circles outperformed their colleagues who did not utilize the program. Students' perceptions of the use of GeoGebra were generally good, according to Shadaan and Leong (2013).

Tay and Wonkyi (2018), investigated the impact of GeoGebra on Senior High School students' GeoGebra performance with an emphasis on circles. Additionally, 49 pupils from a quasi-experimental non-equivalent control group were used in the study". The children were divided into two groups from two schools in the study using purposive sampling, with one group receiving instruction using GeoGebra and the other receiving instruction using the conventional approach. Tay and Wonkyi discovered that pupils who used the GeoGebra software to learn geometry showed improvement. GeoGebra-based instruction, according to Tay and Wonkyi (2018), made lessons in the classroom more engaging and useful for pupils". According to the relevant reviewed literature, GeoGebra has a substantial edge when it comes to teaching mathematics and its applications in daily life. Kemp (2006) discovered in a different study that high-ability Grade 9 males found the lesson to be fascinating. Students were satisfied and involved in the session when utilizing the GeoGebra program, and they went above what the teacher had prescribed in terms of learning.

Angers and Machtmes (2005), reported on instructors' attitudes and beliefs on the use of ICT as a learning tool. They concluded that they have positive attitudes. Also, Sanders and Morrison Shetlar (2002), also reviewed "Students' Attitudes toward technology in Teaching and Learning" Their study confirmed that students' attitudes toward technology are influential in determining the educational benefits of online learning resources and experiences. Much of this research showed that the majority of students see the use of ICT in learning favourably and hence have a positive perception. ICT offers students a learning environment that encourages independent learning as well as more opportunities to share, interact, and collaborate with other students.

IV. METHODOLOGY

The study adopted a quasi-experimental design with pretest-posttest non-equivalent control groups. According to Vanderstoep and Johnson (2009), a quasi-experimental study uses empirical data to determine the causal effects of treatment (intervention) on the population it is intended to reach. The two schools were assigned into two categories, thus experimental and control groups in a non-random manner as part of the research design. The Quasi-experimental research design was employed for this study because the study was carried out in a normal school setting where intact classes were used thereby making randomization impossible. An intervention planned was taken by teaching. The students received planned and delivered instruction. The Researcher used tests and questionnaires to collect data for the study. The researcher administered the pretest before the interventions. The tests contain twenty-five questions (25) for both objective (20) and subjective (5). Two groups (control and experimental groups) wrote the pretest at the same time and same day.

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The Researcher took six weeks for the interventions (treatment) to teach both the concept and the content of Mensuration. Problems were solved in the same period. Mensuration was taught using GeoGebra Software to the experimental group and the control group was taught with the traditional way of teaching. After the intervention posttest was conducted for both groups and marked appropriately. The test item was thoroughly vetted by supervisors and experts in the mathematics education field of study to establish its validity. The reliability of the instrument was ensured by using a pilot study from Bolgatanga Senior High School in the Bolgatanga Municipality on both the Test and questionnaire. A test-retest method was used; the instrument was administered to the respondents and re-administered to them after six weeks. The two sets of scores obtained were correlated using the Pearson Product Moment Coefficient for the test which yielded a coefficient of 0.81 and 0.86 for the pretest and posttest respectively. Also, the reliability of the questionnaire was determined by calculating the Cronbach alpha, which yielded 0.72. Descriptive statistics and t-test statistics at $P \leq 0.05$ level of significance were used to answer the objective and the null hypothesis. The SPSS was used in computing the p-value or Sig. value of the t-test and four-point Likert Scale (1 – 4).

V. RESULTS

➢ *Objective One*

Determine the effects of GeoGebra on students' Performance

Table 1 Statistical Analysis of Pretest Posttest Mean and Standard Deviation Scores of Experimental and Control Group.

	Pretest		Posttest		
Group	**N**	**Mean**	**Std. Deviation**	**Mean**	**Std. Deviation**
Control	30	9.13	3.71	10.67	3.38
Experimental	30	9.10	3.74	14.87	4.69

Source: fieldwork 2022.

A cursory look at Table 1 indicates that the group taught using traditional method teaching (Control group) has a pretest mean of 9.13 with a standard deviation of 3.711 while the group taught using GeoGebra software (Experimental group) had a pretest mean score of 9.10 with a standard deviation of 3.736. The results in the table also show the posttest mean scores and standard deviations for the two groups. The control had a posttest mean of 10.67 with a standard deviation of 3.38 while the Experimental group had a posttest mean score of 14.87 with a standard deviation of 4.69. However, it can be observed from the table that, for each of the groups, the posttest means were greater than the pretest means with the experimental group having the highest mean. This proves that incorporating GeoGebra into teaching mathematics has a more positive effect on students' performance than that of the traditional method.

Ho_1 There is no statistically significant difference between the posttest mean scores of students taught using GeoGebra and students taught without GeoGebra.

Table 2 Independent Samples T-Test for the Experimental and Control Groups' Posttest Results.

Groups	**N**	**Mean**	**Std. Dev.**	**t-value**	**Df**	**Sig-value**
Control	**30**	10.67	3.377	-3.259	58	.003
Experimental	**30**	14.87	4.696			

Source: Field Survey, 2022.

The results in Table 2 indicate that there was a statistically significant difference between the control and experimental groups, as indicated by the significance value of 0.003 from the t-test performed on the means of the 0.05 significance level. We rule out the null hypothesis that there is no statistical difference between the posttest mean scores of the two groups due to the significant value of 0.003. Since we reject the null hypothesis, we can conclude that there is a significant difference between the control and experimental group posttest mean scores in favour of the experimental. This result indicated that students in the experimental group improved from GeoGebra by acquiring a solid conceptual knowledge of the diagrams in the post-test questions, which improved their approaches to offering solutions and the precision of their work. Correct geometric idea visualization will help pupils perform better on accomplishment tests (Shadaan & Leong, 2013).

➢ *Research Question Two*

What is students' perception of GeoGebra as a technological tool in the teaching and learning of Mensuration?

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Table 3 Students' Perceptions of GeoGebra as a Technological Tool in Teaching Mensuration

Statement	S A		A		D		SD		Total	
	N	%	N	%	N	%	N	%	N	%
I was excited about using the GeoGebra software,	21	70	9	30	0	0	0	0	30	100
GeoGebra helped me learn a lot.	19	63.3	11	36.7	0	0	0	0	30	100
During the class activity, I felt comfortable using the GeoGebra program.	9	30	19	63.3	2	6.7	0	0	30	100
I gave my entire attention to the learning process.	23	76.7	7	23.3	0	0	0	0	30	100
The connection between the teacher and students was beneficial to me.	22	73.3	5	16.7	3	10	0	0	30	100
I was able to think creatively during the discussions and Q&A session	20	66.7	4	13.3	6	20	0	0	30	100
GeoGebra made learning mathematics much more enjoyable for me.	23	76.7	7	23.3	0	0	0	0	30	100
I was able to form better connections between previous learning and new learning.	18	60	7	23.3	5	16.7	0	0	30	100
I wish to use GeoGebra all the time in mathematics Class	17	56.7	10	33.3	3	10	0	0	30	100

Table 3 shows the results of students' perceptions. The results above indicated that students gave positive feedback towards the incorporation of GeoGebra software in teaching and learning. The majority of the students strongly agreed (70%) and agreed (30%) that they were excited about using GeoGebra software, meanwhile, 63.3% strongly agreed and 36.7% agreed that the GeoGebra software helped them learn a lot. During the class activity, 30% and 63.3% strongly agreed and agreed respectively that they felt comfortable using the GeoGebra program only 2 students disagree with the statement. Most of the students affirm that they gave their entire attention to the learning process during the GeoGebra lesson (23% strongly agreed and 76.7% agreed with the statement) while 23.3% disagreed. For student-teacher relationships, 73.3% (strongly agreed) and 16.7% agreed that there were good relationships between the teacher and students concluding that the teacher-student relationship was beneficial. Finally, 56.7% strongly agreed and 33.3% agreed that GeoGebra software should be used all the time in mathematics lessons. However, some students disagreed (10%) that the GeoGebra software should not be used during mathematics.

VI. DISCUSSION

The results in Table 1 indicate that the mean scores of students during the pretest are very close. This implies that all the two groups are of the same level in terms of their academic performances. Hence the results support the assumption that students in each treatment group had equivalent mathematical skills. For the posttest result, though there was an improvement in the academic performance of students in both groups after treatment, it is obvious from Table 1 that, the difference found was in favour of the experiment group students in terms of the post-test mean scores.

The analysis of the posttest results revealed that there was a statistically significant difference ($p = 0.003 < 0.05$) between the control and experimental groups; hence hypothesis two was rejected. Hence, based on the p-value and sig. value it can be inferred that the students who used Geoebra software performed better than their counterparts taught using the traditional method. The findings confirm Zengina, Furkan, and Kutlucaa's (2012) results. According to their findings, GeoGebra was able to raise students' performance in trigonometry more effectively than the conventional method of teaching and learning. The findings also supported the results of Guven (2012), whose findings indicated that the experimental group outperformed the control group in terms of academic accomplishment as well as levels of learning of transformation geometry when GeoGebra was used as a teaching tool. The results support Shadaan and Leong (2013) study. The study's results revealed that pupils who used GeoGebra to learn about circles outperformed their colleagues who did not utilize the program. Finally, from Table 3 it was found that students' responses to the questionnaire that the students have a positive perception towards the use of GeoGebra learning, this confirmed the assertion made by Shadaan & Leong (2013) that students have a positive perception.

VII. CONCLUSION

GeoGebra as a teaching and learning tool enhanced students' performance in mathematics, hence it would be of great advantage when GeoGebra is incorporated as a teaching and learning tool. Also, students' perceptions of GeoGebra as a technological tool in teaching Mensuration were positive. Therefore, students would embrace the software when it is introduced as a technological tool.

RECOMMENDATION

It is recommended that; policymakers and mathematics curriculum developers ensure GeoGebra is made an integral part of the Senior High School Curriculum and teachers should be trained on how to use it. Teachers should take advantage of ICT software such as GeoGebra in teaching mathematics in Senior High Schools since students are happy using GeoGebra. The Government should equip the SHS ICT Labs for students to use.

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