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Evaluation of Impact of UJ-Math Graphing Tool (UJ-MaGT) on Secondary School Students' Graphing Ability

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ABSTRACT

In recent years, there has been renewed call and effort by Nigerian government to encourage the enrollment of pupils into science, technology, engineering and mathematics; (STEM) subjects. Graph construction is a veritable and indispensable skill required by anyone that engages in a STEM subject. Yet, data from the West African senior school certificate exams (WASSCE) – physics practical – chief examiner's annual report has revealed serious deficiency in graph construction by secondary school leavers. In an attempt to solve this problem, an app called UJ-Math Graphing Tool (UJ-MaGT) was developed with the aim of incorporating its algorithm in a scientific calculator. The technology was evaluated among 903 senior secondary school students within Jos. Pre-test and post-test were conducted and achievement scores were obtained by grading the test scripts in accordance with West African Examination Council's (WAEC) marking scheme. Analysis of variance (ANOVA) was carried out using SPSS software. Results show that there was no statistical difference (P>0.05) amongst the groups before the intervention, the null hypothesis "There is no significant difference in achievement score and gap before intervention of UJ-Math Graphing Tool (UJ-MaGT) in graph plotting" was retained. Furthermore, the null hypothesis "There is no significant difference in achievement score and gap after intervention of UJ-Math Graphing Tool (UJ-MaGT) in graph plotting" was rejected because there exist a statistical significant difference (P<0.05) amongst the groups after the intervention. It is therefore concluded that the technological intervention has significant impact on the performance of the students in graph construction.

Keywords:
Graph construction,
Data processing,
Graphing Calculator,
Data Science,
Graphing Technologies.

INTRODUCTION

In recent years, there has been renewed call and effort by Nigerian government to encourage the enrollment of pupils into science, technology, engineering and mathematics (STEM) subjects. This is a deliberate policy statement to prepare the future generation for self-reliance. The call has become necessary as the enrollment rate into STEM subjects does not match the geometric increase in the population of the country. Furthermore, it is no news that countries that do well in STEM disciplines are equally leaders economic wise. One of the reasons for the lag in the enrollment rate is the fear of the perceived difficulty associated with STEM subjects.

Graphing is a veritable and indispensable skill required by anyone that engages in a STEM subject. Despite this, data from the West African senior school certificate exams (WASSCE) – physics practical – chief examiner's annual report has revealed serious deficiency in graphing by secondary school leavers (Mafuyai et al. 2013). In attempt to solve this problem, an app called UJ-Math Graphing Tool (UJ-MaGT) was developed with the aim of incorporating its algorithm in a scientific calculator (Mafuyai et al. 2020). This is useful in plotting graphs both in Mathematics and Physics. Recent study that evaluated the efficacy of the app among students of the University of Jos has shown a significant improvement in achievement scores in graph plotting. More interesting is the fact that achievement gap was overwhelmingly closed. This shows that the below average students who otherwise would give up on graphing, now have reasons not to do so. A follow up survey study revealed that students feel highly motivated to engage in concepts that require graphing and will plot graphs at anytime if the app is available. This resounding success gave rise to this study which aims to validate the efficacy of the app among secondary school students. This is necessary because secondary school is the foundation for graphing skill and the reported poor performance in this level requires research attention. The purpose of the study was to evaluate the impact of UJ-Math Graphing Tool (UJ-MaGT) on secondary school students' performance in graph construction and objectives were:

i. To determine the effect on achievement scores by comparing the scores using anaalysis of variances
ii. To determine the effect on achievement gap by examining the standard deviations of the mean class mark

And the research hypotheses include:

i. There is no significant difference in achievement score and gap before intervention of UJ-Math Graphing Tool (UJ-MaGT) in graph plotting
ii. There is no significant difference in achievement score and gap after intervention of UJ-Math Graphing Tool (UJ-MaGT) in graph plotting.

The origin of classroom technology can be traced to the invention of "adding machine" – the calculator (Maxwell, 1981). Calculator became a game changer in the way STEM courses are learned (Dick, 1992). The innovation that swept the calculator industry has resulted in more sophisticated calculators with capabilities for most of the scientific applications such as integration, differentiation, graphing etc. TI-84, TI-Nspire CX, Casio etc. are examples of calculators with sophisticated capabilities for scientific application. While these advancements in the calculator industry are appreciated, many educators still have reservation for some of the technological advancements in calculator. Study by Brown et al., (2007) revealed that some teachers believe the use of calculator can be a means of getting answer without understanding mathematical process. However, the overall findings of the study supported the use of calculator in teaching and learning of mathematics as it enhances and motivates interest in mathematics. West African Examination Council (WAEC) which is responsible for the administering of the West African Senior School Certificate Examination (WASSCE) does not allow every type of calculator into the examination hall as they believe some calculators can aid exam malpractice.

Apart from the fear of exam malpractice, others believe technology can inhibit the learners' understanding of the concepts (Hembrooke and Gay, 2003; Schleicher, 2015). This is particularly the case with graphing calculators (Milou, 1999). Many believe that plotting using paper and pencil supports active learning which enhances learner's understanding of concepts being studied (davidwees.com, 2012;deWinstanley, et al, 2002; McDermott, et al, 2014). However, other studies revealed that calculator technology; especially graphing calculator has positive impact on some areas of learning (Smith and Shotsberger, 1997; Ellington, 2006). Smith and Shotsberger (1997) specifically pointed out that graphing calculator was found to be very helpful to students in graphing logarithmic functions, exponential functions, higher order functions, and lines. Other studies reported positive impact of calculator on gender-based performance; with the technology improving the performance of females far more than males (Ruthven, 1990; Dunham, 1995). Whatever the argument may be, the poor performance of students in WASSCE's physics practical exams (Waeconline.org.ng, 2017) over the years and myriad of problems faced by students in constructing and interpretation of graphs (Hattikudur, et al, 2012; Kali, 2005; Roth and McGinn, 1996) are a clear indication of the need for an intervention to help improve learning outcome. Some of the areas of difficulty include choosing of suitable scales, plotting of data points, reading of intercepts and determination of slope etc. (Delgado and Lucero, 2015;Waeconline.org.ng, 2017;Dunham and Osborne, 1991).

To maintain the need for conceptual understanding, retention and higher achievements that come through active learning(Freeman, et al, 2004; deWinstanley, et al, 2002; McDermott, et al, 2014) of which graph plotting using pencil and paper graphing technique is an active learning activity and equally eliminate challenges militating against excellent performance in WASSCE's physics practical exam, UJ-MaGT(see: https://play.google.com/store/apps/details?id=com.bitrient.magt) was developed. UJ-MaGT was designed as a mobile app for two reasons: The acceptability of mobile devices all over the world and the flexibility for validation of efficacy that app can provide.

The wide acceptability of mobile devices around the world is leaving no aspect of human endeavour unchanged. Particularly, the educational sector has seen a rapid change over the few years as a result of this technology. For instant, the gap between education and applications (Apps) is rapidly closing in the western world. Educational App.com has developed and distributed many educational apps worldwide in different areas of studies such as sciences, mathematics, humanities etc. For instance, in mathematics, apps such as "mental Abacus", "show me the money Part1", "Math Racer 3.0" etc. have been in use by students and over 2000 teachers in about 1000 schools in UK (http://www.educationalappstore.com, 2015). Also, in US, the adoption of 1:1 iPad program has covered 600 school districts (Bonnington, 2012). A study conducted by Apple in conjunction with textbook publishers Houghton Mifflin Harcourt performed a pilot study using an iPad text for Algebra 1 courses and found that 20% more students (78% compared to 59%) scored 'Proficient' or 'Advanced' in subject comprehension when using tablets rather than paper textbook counterparts (Bonnington, 2012). This sudden increase in the use of educational Apps as teaching aids as a result of the availability of mobile devices has started attracting the attention of researchers around the world. For example, a research paper by Kamlesh and Akash (2013) which is based on the study carried out in Babarian Institute of Technology on 10 selected students to evaluate the efficacy of Mobiles-Assisted Language Learning (MALL) shows that there is positive impact of technology on the students. Teemu, et'al (2014) studied how the use of apps could support reflection in learning in K-12 education and concluded that there is potential for fostering the practice of reflection in classroom learning through the use of apps for audio-visual recordings. This finding is interesting as reflection plays an important role in collaborative progressive inquiry or project-based learning (Minna, 2008; Rahikainen, et'al 2001). This emerging trend of using apps in enhancing learning informed the development of UJ-MaGT for ease of evaluation of intervention required to solve the challenge of graphing among students.

MATERIALS AND METHODS

The material used include: UJ-Math Graphing Tool (UJ-MaGT), Graph papers, Meter rules, Pencils, Test Questions, SPSS software, and Survey questionnaire. The UJ-Math Graphing Tool was installed on computers during the first term of 2023/2024 academic session. The study area was Jos metropolis. Ten secondary schools were recruited – four were government secondary schools labeled GSS1, GSS2, GSS3, and GSS4, three were for-profit private secondary schools labeled PPSS1, PPSS2, and PPSS3, and three were not-for-profit (mission owned) private secondary schools labeled NPPSS1, NPPSS2, and NPPSS3.

The population included SS1 &2 students and the sampling technique used was census study. The entire population in each class was studied. Students were randomly categorized into control and treatment groups. A pre-treatment achievement test was administered to both groups. Thereafter, the control group received 45 minutes of regular lessons periods on graph related topics in their usual classrooms while the treatment group were taught same topics in the computer labs where they used the app in the process of learning for the same 45 minutes of regular lessons periods. At the end of the term, both groups wrote the same post treatment achievement test in the same hall while the treatment group, in addition, completed a survey questionnaire.

The students' graphs were graded in accordance to the West African Examination Council (waec) practical grading standard. Each graph was awarded a total score of 15 marks. The marks were distributed to the seven technical aspects of graph plotting as follows: 1mark for axis correctly distinguished (A), 2marks for suitable scales (SC), 5marks for correctly matched points (PT), 5marks for slope determination (SL), $^1/_2$marks for a correct line of best fit (L),$^1/_2$marks for a suitable Right-angle Triangle(RT) and 1mark for intercept (I). The graded scripts were then vetted by an expert with over ten years of experience in grading Physics practical for waec. The purpose was to ensure that scripts were graded uniformly and in accordance to the standard rules and to reduce biasness to the barest minimum. The scores for various aspects that constitute the technicalities of graph plotting were determined and summed up.

RESULTS AND DISCUSSION

Results of Analysis of pre-treatment achievement test scores

Table 1: Pre-treatment Descriptive statistics for SS1

Descriptives								
Scores	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
GSS1C	26	3.6923	2.73158	.53571	2.5890	4.7956	.50	11.00
GSS1T	25	3.8800	3.64086	.72817	2.3771	5.3829	.00	12.50
GSS2C	28	3.9107	3.55135	.67114	2.5336	5.2878	.00	12.50
GSS2T	28	4.1071	3.13982	.59337	2.8896	5.3246	.50	11.00
GSS3C	31	4.4677	3.70346	.66516	3.1093	5.8262	.50	14.50
GSS3T	31	3.8871	3.05699	.54905	2.7658	5.0084	.50	11.00
GSS4C	30	4.5833	3.70946	.67725	3.1982	5.9685	.50	14.50
GSS4T	30	4.6833	3.87851	.70812	3.2351	6.1316	.50	14.50
PPSS1C	18	4.6389	2.55990	.60337	3.3659	5.9119	1.00	10.00
PPSS1T	18	4.6944	2.86017	.67415	3.2721	6.1168	.50	10.00
PPSS2C	16	5.1875	3.05982	.76496	3.5570	6.8180	1.00	12.50
PPSS2T	16	5.4375	2.98817	.74704	3.8452	7.0298	1.00	12.50
PPSS3C	21	5.0476	2.81471	.61422	3.7664	6.3289	1.00	12.50
PPSS3T	21	5.2381	2.76866	.60417	3.9778	6.4984	1.00	12.50
NPPSS1C	19	4.4211	2.10992	.48405	3.4041	5.4380	1.00	8.50
NPPSS1T	19	4.6842	2.38753	.54774	3.5335	5.8350	1.00	9.50
NPPSS2C	18	4.3056	2.10838	.49695	3.2571	5.3540	1.00	8.50
NPPSS2T	18	4.5833	2.41472	.56916	3.3825	5.7841	1.00	9.50
NPPSS3C	20	4.5250	2.10560	.47083	3.5395	5.5105	1.00	8.50
NPPSS3T	20	4.7750	2.35905	.52750	3.6709	5.8791	1.00	9.50
Total	453	4.4757	3.01883	.14184	4.1970	4.7545	.00	14.50

Table 2: Pre-treatment ANOVA Statistics for SS1

ANOVA

Scores	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	96.728	19	5.091	.548	.940
Within Groups	4022.505	433	9.290		
Total	4119.233	452			

Robust Tests of Equality of Means

Scores	Statistic[a]	df1	df2	Sig.
Welch	.533	19	151.022	.944
Brown-Forsythe	.587	19	404.164	.916

a. Asymptotically F distributed.

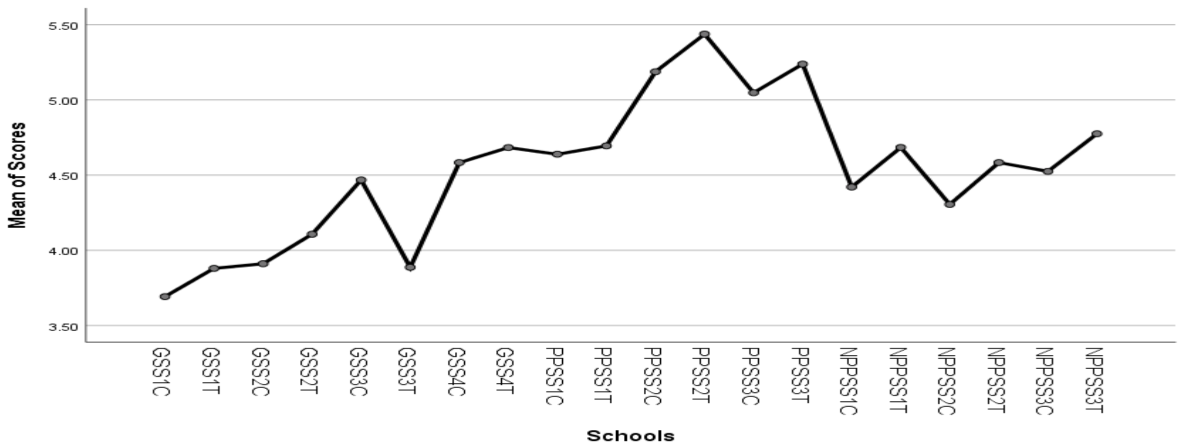

Figure 1: Means plot of pre-treatment Achievement test score for SS1 groups of all the school

Table 3: Pre-treatment Descriptive statistics for SS2

Descriptives

Scores	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
GSS1C	26	6.7692	1.99113	.39049	5.9650	7.5735	4.00	11.00
GSS1T	25	6.7400	2.72381	.54476	5.6157	7.8643	2.00	12.50
GSS2C	28	5.8929	2.71265	.51264	4.8410	6.9447	2.00	12.50
GSS2T	28	6.2500	2.33135	.44058	5.3460	7.1540	3.00	11.00
GSS3C	31	6.6129	2.80390	.50359	5.5844	7.6414	3.50	15.00
GSS3T	31	6.5161	2.42034	.43471	5.6283	7.4039	3.00	11.00
GSS4C	30	7.0000	2.75118	.50229	5.9727	8.0273	3.50	15.00
GSS4T	30	7.0167	2.94045	.53685	5.9187	8.1146	3.50	15.00
PPSS1C	18	7.1111	1.85944	.43827	6.1864	8.0358	4.00	10.50
PPSS1T	18	6.9444	2.53150	.59668	5.6856	8.2033	2.00	11.50
PPSS2C	16	6.5000	2.33809	.58452	5.2541	7.7459	4.00	12.50
PPSS2T	16	6.5625	2.39357	.59839	5.2871	7.8379	4.00	12.50
PPSS3C	21	7.1667	2.39444	.52251	6.0767	8.2566	4.00	12.50
PPSS3T	21	7.0238	2.29388	.50057	5.9796	8.0680	4.00	12.50
NPPSS1C	19	6.6579	1.85632	.42587	5.7632	7.5526	4.00	11.00
NPPSS1T	19	6.5000	2.03443	.46673	5.5194	7.4806	4.00	10.00
NPPSS2C	18	8.1944	8.20892	1.93486	4.1122	12.2766	4.00	40.50
NPPSS2T	18	7.9722	2.45232	.57802	6.7527	9.1917	4.00	12.50
NPPSS3C	20	7.1250	1.91857	.42901	6.2271	8.0229	4.00	11.50
NPPSS3T	20	7.0250	1.75075	.39148	6.2056	7.8444	4.00	10.50
Total	453	6.8344	2.85454	.13412	6.5709	7.0980	2.00	40.50

Table 4: Pre-treatment ANOVA Statistics for SS2

ANOVA					
Scores	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	110.569	19	5.819	.705	.814
Within Groups	3572.514	433	8.251		
Total	3683.083	452			

Robust Tests of Equality of Means

Scores	Statistic[a]	df1	df2	Sig.
Welch	.650	19	150.486	.862
Brown-Forsythe	.668	19	100.689	.842

a. Asymptotically F distributed.

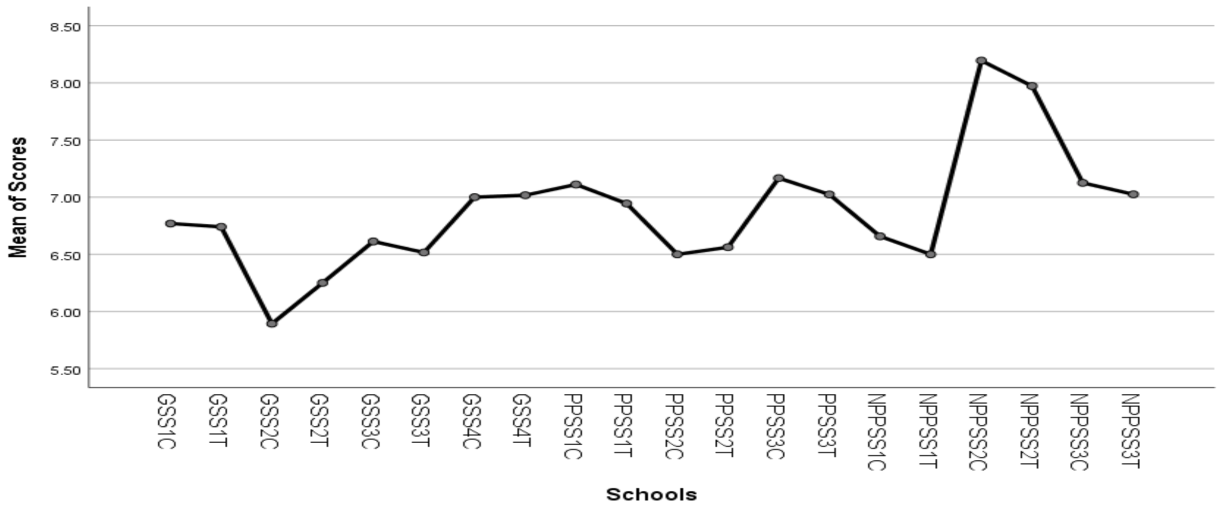

Figure 2: Means plot of pre-treatment Achievement test score for SS2 groups of all the schools

Results of Analysis of post-treatment achievement test scores
Table 5: Post-treatment Descriptive statistics for SS1

Descriptives								
Scores	**N**	**Mean**	**Std. Deviation**	**Std. Error**	**95% Confidence Interval for Mean**		**Minimum**	**Maximum**
					Lower Bound	**Upper Bound**		
GSS1C	26	7.0000	1.87083	.36690	6.2444	7.7556	4.50	11.00
GSS1T	25	10.3800	1.43091	.28618	9.7893	10.9707	7.50	13.50
GSS2C	28	6.3929	2.55806	.48343	5.4009	7.3848	2.00	12.50
GSS2T	28	10.7857	1.33631	.25254	10.2675	11.3039	7.50	13.00
GSS3C	31	7.0323	2.82529	.50744	5.9959	8.0686	3.50	15.00
GSS3T	31	10.7097	1.34644	.24183	10.2158	11.2036	7.50	13.00
GSS4C	30	7.2333	2.80926	.51290	6.1843	8.2823	3.50	15.00
GSS4T	30	11.3500	1.16078	.21193	10.9166	11.7834	9.50	15.00
PPSS1C	18	7.1111	1.85944	.43827	6.1864	8.0358	4.00	10.50
PPSS1T	18	9.9444	1.34917	.31800	9.2735	10.6154	7.50	12.50
PPSS2C	16	7.0000	2.36643	.59161	5.7390	8.2610	4.00	12.50
PPSS2T	16	10.0625	1.78769	.44692	9.1099	11.0151	7.00	12.50
PPSS3C	21	7.4048	2.42703	.52962	6.3000	8.5095	4.00	12.50
PPSS3T	21	9.9762	1.88730	.41184	9.1171	10.8353	6.00	12.50
NPPSS1C	19	6.8684	1.88445	.43232	5.9601	7.7767	4.00	12.00
NPPSS1T	19	10.1842	1.87979	.43125	9.2782	11.0902	7.00	13.50
NPPSS2C	18	8.4722	8.39550	1.97884	4.2972	12.6472	4.00	41.50
NPPSS2T	18	10.3056	1.63724	.38590	9.4914	11.1197	7.00	12.50
NPPSS3C	20	7.4250	2.09809	.46915	6.4431	8.4069	4.00	11.50

NPPSS3T	20	10.8250	1.91445	.42808	9.9290	11.7210	7.00	13.50
Total	453	8.8344	3.06568	.14404	8.5514	9.1175	2.00	41.50

Table 6: Post-treatment ANOVA Statistics for SS1

ANOVA					
Scores	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	1389.439	19	73.128	11.077	.000
Within Groups	2858.644	433	6.602		
Total	4248.083	452			

Robust Tests of Equality of Means

Scores	Statistic[a]	df1	df2	Sig.
Welch	19.813	19	149.429	.000
Brown-Forsythe	10.059	19	67.120	.000

a. Asymptotically F distributed.

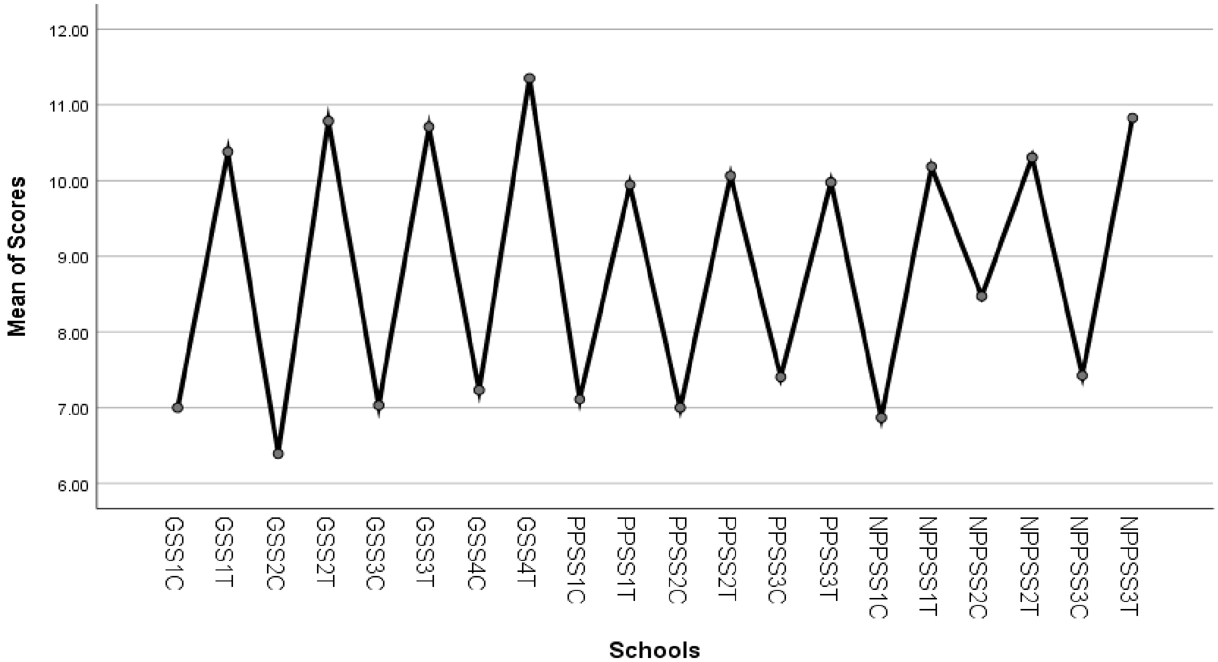

Figure 3: Means plot of post-treatment Achievement test score for SS1 groups of all the schools

Table 7: Post-treatment Descriptive statistics for SS2

Descriptives								
Scores	**N**	**Mean**	**Std. Deviation**	**Std. Error**	**95% Confidence Interval for Mean**		**Minimum**	**Maximum**
					Lower Bound	**Upper Bound**		
GSS1C	26	7.0000	1.87083	.36690	6.2444	7.7556	4.50	11.00
GSS1T	25	11.7800	1.54839	.30968	11.1409	12.4191	7.50	14.50
GSS2C	28	6.3929	2.55806	.48343	5.4009	7.3848	2.00	12.50
GSS2T	28	12.2143	1.64671	.31120	11.5758	12.8528	7.50	15.00
GSS3C	31	7.0323	2.82529	.50744	5.9959	8.0686	3.50	15.00
GSS3T	31	12.2258	1.55370	.27905	11.6559	12.7957	7.50	15.00
GSS4C	30	7.2333	2.80926	.51290	6.1843	8.2823	3.50	15.00
GSS4T	30	12.6833	1.12559	.20550	12.2630	13.1036	9.50	15.00
PPSS1C	18	7.1111	1.85944	.43827	6.1864	8.0358	4.00	10.50
PPSS1T	18	11.0556	1.62597	.38325	10.2470	11.8641	7.50	13.50
PPSS2C	16	7.0000	2.36643	.59161	5.7390	8.2610	4.00	12.50
PPSS2T	16	11.1250	1.87528	.46882	10.1257	12.1243	8.00	13.50
PPSS3C	21	7.4048	2.42703	.52962	6.3000	8.5095	4.00	12.50
PPSS3T	21	11.0714	1.92539	.42016	10.1950	11.9479	8.00	13.50

NPPSS1C	19	6.8684	1.88445	.43232	5.9601	7.7767	4.00	12.00
NPPSS1T	19	11.2368	2.05729	.47198	10.2453	12.2284	8.00	14.50
NPPSS2C	18	8.4722	8.39550	1.97884	4.2972	12.6472	4.00	41.50
NPPSS2T	18	11.1389	1.66102	.39151	10.3129	11.9649	8.00	13.50
NPPSS3C	20	7.4250	2.09809	.46915	6.4431	8.4069	4.00	11.50
NPPSS3T	20	10.7250	1.88816	.42220	9.8413	11.6087	8.00	13.50
Total	453	9.3974	3.45258	.16222	9.0786	9.7161	2.00	41.50

Table 8: Post-treatment ANOVA Statistics for SS2

ANOVA					
Scores	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	2446.505	19	128.763	18.955	.000
Within Groups	2941.472	433	6.793		
Total	5387.977	452			

Robust Tests of Equality of Means

Scores	**Statistic[a]**	**df1**	**df2**	**Sig.**
Welch	34.154	19	149.468	.000
Brown-Forsythe	17.266	19	70.412	.000

a. Asymptotically F distributed.

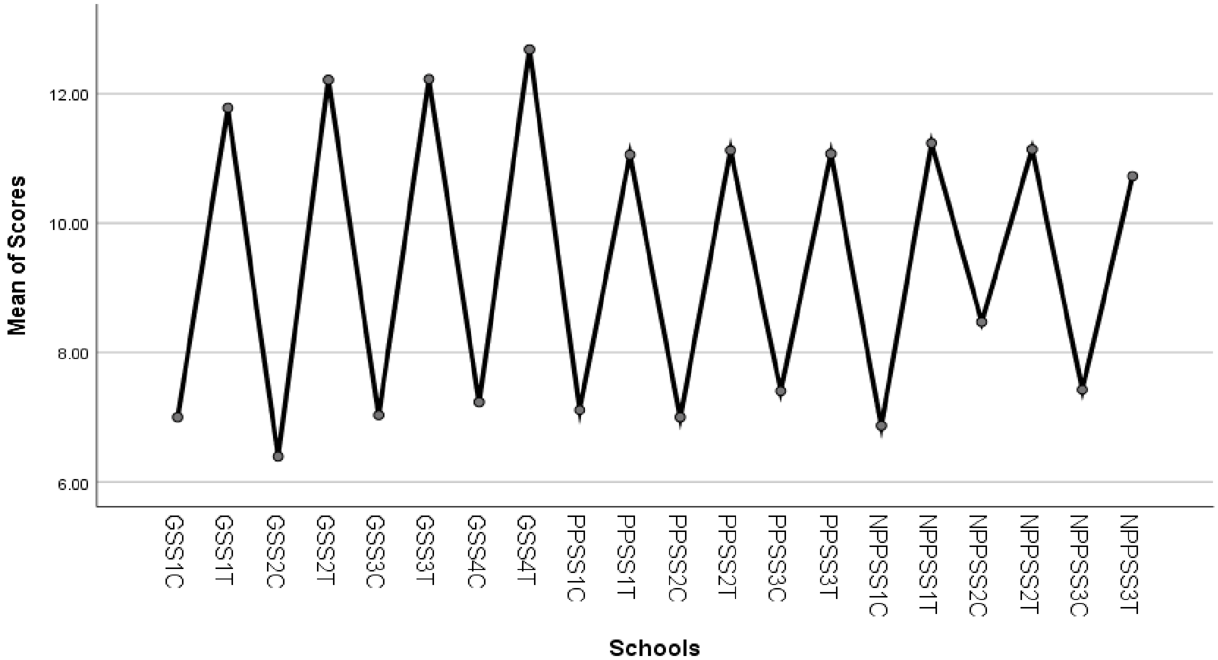

Figure 4: Means plot of post-treatment Achievement test score for SS2 groups of all the school

Discussion

At the beginning of the term, all the senior secondary school 1 (SS1) students must have transitioned from junior secondary school 3 (JSS3) with poor knowledge of graph construction since such syllabus is not covered at junior secondary school level. This is clearly seen in Table 1. Table 1 is characterized with low class means and high standard deviation which imply poor knowledge of graph construction and wide achievement gap between the below-average and the above-average students in the class. Similarly, Table 3 which gives the descriptive statistics of the achievement scores of the students of senior secondary 2 (SS2) reveals low class means and standard deviations. However, the class means are higher than those of SS1 implying that the SS2 students could have had some knowledge of graph construction during their SS1 academic year.

The ANOVA (Table 2 & 4) show no statistical difference exist ($p>0.05$) between any of the groups in all the schools involved in the studies; neither SS1 nor SS2 groups. This shows that the students' level of understanding of graph construction was fairly similar and hence, no significant bias is expected due to random grouping of the students into control and treatment groups and selection of participating schools. Furthermore, a trend can be observed in Figure 1 and 2. The class means of students from for-profit private secondary schools (PPSS) and not-for-profit private secondary schools (NPPSS) appears to be higher than those of students of government secondary schools (GSS). This may not be surprising as those students in private secondary schools often come from a high-social-status families and social status has been shown to correlate with academic performance.

The class means for the treatment groups (Table 4 and 6) show great improvement with a very low standard deviation implying that achievement gap between the below-average and above-average students being narrowed. The ANOVA (Table 5 and 7) shows that statistical difference ($P<0.05$) exist amongst the groups and the POST HOC TESTS reveal that the statistical difference is between treatment groups and control groups implying that the intervention was effective. Figure 3 and 4 clearly show that the mean scores of the treatment groups are higher than those of the control groups. The trends in Figure 3 and 4 show a marked improvement in the class means of the treatment groups. In fact, the government secondary schools; GSS1T, GSS2T, GSS3T and GSST4 seems to improve better than those of private schools. This clearly shows that given an equal opportunity, the students in government secondary school could compete favourably with their counterparts in private secondary schools.

CONCLUSION

In conclusion, the result of the studies so far reveals that there was no statistical significant amongst the groups in all the participating schools before the intervention. Therefore, the null hypothesis is retained. However, after the intervention, a statistical difference exists between the treatment and the control groups irrespective of class and school. Hence the null hypothesis is rejected. It is concluded that graphing technology has significant impact on the students' graph construction accuracy and achievement gap.

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