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Effects of Computer-Aided Instruction (CAI) on Junior High School Students' Achievement and Retention

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The goal of this study was to find out how computer-aided instruction affects basic school students' achievement and retention in integrated science in Komenda-Edina-Eguafo-Abrim Municipality in Ghana. A non-randomized pretest-posttest group design was used in this investigation. The sample for the study consisted of 80 Junior High School (JHS) 2 students drawn from two schools. The experimental and control groups were assigned randomly to the two selected schools. The students were given a validated integrated science achievement test with a reliability value of 0.926. At a significance level of 0.05, Analysis of Covariance (ANCOVA) was employed to test the two null hypotheses of the investigation. The findings revealed that JHS students who were taught with computer-aided instruction performed and remembered information better than those taught with conventional instruction. From the findings of the study, JHS teachers are encouraged to use computer-aided instruction to teach integrated science.

Key words: *Computer-aided instruction; students' achievement; retention; integrated science*

INTRODUCTION

The widespread use and interest in digital and hybrid computers as an instructional tool did not occur until the 1980s. Computers were first used in education and training at a much earlier date. Much of the early work that computers introduced in education was done in the 1950s by researchers at International Business Machine Corporation (IBM), who developed the first Computer-Assisted Instruction (CAI) author language and designed one of the first CAI programs to be used in public schools. Students followed the commands on the computer screen receiving rewards for correct answers within the framework of behaviorist approaches (Osokoya, 2013).

During the 1990s, digital and hybrid computers eventually started to have a major impact on instructional practices in schools. Science researchers think that learning with technology is a way to develop problem-solving abilities and learner independence with the aid of technological and educational developments. The cognitive approach to instructional technology emphasized on looking at how we know rather than how we respond, and analyzing how we plan and strategize our thinking, remembering, understanding, and communicating (Berg, 2003).

Later in 1995, rapid advances in computer and other digital technology, as well as the Internet, led to a rapidly increasing interest in and use of computers for instructional purposes (Reiser, 2001). The improvements in technology are unavoidably mirrored in the educational systems in the 21st century. The United Nations Educational, Scientific, and Cultural Organization (UNESCO), is of the view that adopting IT into the educational systems has the potential of increasing the quality of education delivery as well as facilitating greater access to information and services by marginalized groups and communities (Sarkar, 2012). Most schools around the world use computers and its related technologies have been integrated into the various disciplines in academics.

Most of the researchers and educators try to use technologies in various subject matters which changes the nature, concepts and methods of work in each subject. For example, in science education, the way of teaching and learning, the roles and functions of most concepts have changed with the use of technology. Furthermore, teachers can now use the computer as an aid to manage classroom activities which has a lot of roles to play in the curriculum which can range from tutor to student tools.

Furo (2015) explained that CAI refers to instruction or remediation presented on a computer. It is the use of computers as an interactive instructional technique to present the instructional materials and monitor the learning that takes place. Research conducted by Akpan and Andre (2000) examined the prior use of simulation of frog dissection in improving students' learning of frog anatomy and morphology. They indicated that students who received simulation before dissection and simulation only learned significantly more anatomy than students who received dissection only. Visual sense is a critical factor for improving learning since individuals remember only 10% of what they hear, 30% of what they read, and 80% of what they see and do (Lester, 2012). Also, Stokes (2002) and Konomi (2014), are of the view that the overall success of any lesson in the science classroom relies on the teacher's use of computer-aided instruction to enrich and supplement the subject matter taught.

CAI has been shown to have a positive impact on student achievement and engagement in science. For instance, a study conducted in the Philippines found that students exposed to CAI obtained "fairly satisfactory" results in the post-test, while those exposed to non-CAI showed "needs improvements" both in the pretest and post-test. Moreover, for students' engagement in science, the CAI group had a high engagement level for affective, cognitive, and behavioral domains (Dap-og & Orongan, 2021). Also, Chevalère et al. (2021) compared the effectiveness of CAI and inquiry-based learning (IBL) in science and technology. The study involved 509 middle-school students who received either IBL or CAI for a period of four to ten weeks. After controlling for students' prior knowledge and socio-cognitive factors, multilevel modeling showed that CAI was more effective than IBL. The benefits of CAI were stable across students' socioeconomic status and academic self-concept, but were particularly pronounced for those with higher working memory capacity (Chevalère et al., 2021).

While there is substantial evidence that CAI can enhance learning at all educational levels, it has not been very effective in some applications, especially those involving abstract reasoning and problem-solving processes (Bonsu et al., 2020). However, the evidence suggests that CAI has a positive impact on student achievement and engagement in science (Chevalère et al., 2021).

In the current era where technology has reached its heyday, several studies have been conducted to investigate the effectiveness of visual aids compared to verbal instruction (Akerele & Afolabi, 2012; Fakomogbon, Bada, Omiola, & Adebayo, 2012; Joshi, 1997; Maduna, 2002; Quarcoo-Nelson, Buabeng, & Osafo, 2012;). For example, Quarcoo-Nelson, Buabeng, and, Osafo (2012) found that high school students who were taught with visual aids performed better than those who were taught using the traditional method. Similarly, Akerele and Afolabi (2012) concluded that when video is used in teaching, it enhances learners' positive attitude towards the course. In addition, it positively affects their performance.

Like in other public Junior High Schools in Ghana, poor students' academic performance in integrated science is noted in some schools in the Elmina circuit of the Komenda Edina Eguafo Abrem (K.E.E.A) municipality (Akyeampong et al., 2013). Given the many advantages of computer-assisted teaching, it is hypothesized that this type of curriculum could help the students in this study to perform better academically and retain more information about integrated science. The study therefore aimed at finding out whether CAI more positively affects students' achievement and retention in integrated science in junior high schools when compared to the traditional technique. Therefore, the following null hypotheses were evaluated at the 0.05 level of significance:

1. Ho_1. There is no statistically significant difference in the posttest mean and pretest mean achievement scores of students who are taught integrated science using computer aided instruction and those taught using the traditional method.
2. Ho_2. There is no statistically significant difference in the mean retention scores of the students who are taught integrated science using computer aided instruction and those taught using traditional method.

THEORETICAL REVIEW

This study was based on the principles of behavioural and constructivist learning theories. These theories provide a framework for teaching and learning in the classroom. The study found that these theories are relevant to effective teaching and learning, particularly in the context of computer-aided learning and provision of undetectable information. The study also discusses the classroom implications of these theories.

Behaviorist Learning Theory

Behaviourist Learning Theory is a psychological theory of learning that emphasizes the role of environmental factors in shaping behavior. B.F. Skinner, a leading American psychologist, was a proponent of this theory. According to Skinner, learning is a process of 'conditioning' in an environment of stimulus, reward, and punishment (Skinner, 1968). In this context, the study uses Skinner's strategies to influence student behaviour by applying these principles to address how students respond to technological exposure, as exemplified by the use of CAI . The study suggests that videos and visuals can serve as tools to assess students' academic performance. To maximize the benefits from a behavioral perspective, the study recommends enhancing the CAI program by integrating features that provide immediate feedback and positive reinforcement. These elements can serve as motivators, encouraging active engagement among students (Teaching Channel. 2021). The CAI program should incorporate opportunities for repetition and practice, allowing students to consolidate their learning while maintaining clear and explicit learning objectives that guide their educational journey .

Constructivist Learning Theory

Constructivist learning theory is a learning theory that emphasizes the active role of learners in building their own understanding. It posits that individuals construct knowledge based on their prior understanding of a subject (Driscoll, 2000). In the context of this study, students were encouraged to interact with visuals and study materials, which is in line with the theory's emphasis on active engagement. The application of Constructivist theory is particularly relevant as it deepens our comprehension of the teaching and learning environment, ultimately nurturing academic growth (Mcleod, 2023)

From a Constructivist perspective, CAI program should further encourage active engagement through opportunities for exploration and experimentation, integration of prior knowledge, and the cultivation of collaborative learning experiences. Additionally, it should facilitate reflective thinking and critical content analysis while providing information in various formats to accommodate diverse learning styles (Mcleod, 2023). The framework is shown in Figure 1.

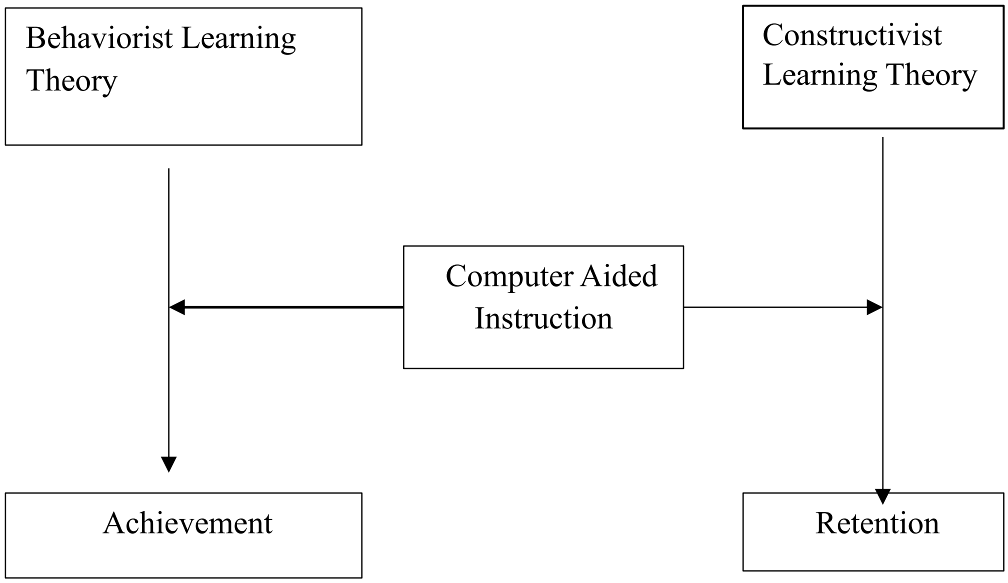

Figure 1: Theoretical framework

METHODOLOGY

Research Design

The study utilized a non-randomized pretest-posttest quasi-experimental design. Hence, only one of the groups received treatment. According to Cohen and Ledford (1994), a quasi-experiment is an experimental condition in which the researcher assigns, but not randomly, participants to groups because the experimenter cannot artificially create groups for the experiment. The pre-test and post-test quasi-experimental design used in this study has been described in Table 1. The principle behind this design is a non-randomise assigned respondent between two groups, a control group (A) and an experimental group (B). Both groups were pre-tested and post-tested, the ultimate difference being that one group was administered the treatment.

Table 1: Description of the design for the study

Group	Pre-test	Treatment	Post-test	Retention	Post Post-test
A	O_1	-	O_2	R	O_3
B	O_4	X	O_5	R	O_6

The quasi-independent variable was the computer-assisted learning/treatment. It is the variable that was manipulated in order to test its effect on the achievement and retention of integrated science knowledge on the experimental group. The control group was not treated but subjected to the traditional methods of learning. The results of both groups from the pre-test and final post-test were obtained so that the overall effect could be compared.

Sample and Sampling Procedure

The sample size for the study consisted of 80 subjects with 40 from each of the two JHS involved in the study, taking cognizance of equal representation of samples in the target population. The selected subjects were in JHS 2. The accessibility of these institutions for the study was a key factor in their selection. The multi-stage sampling technique was used in selecting the sample for this study. Purposive sampling was used in selecting the schools, non-random sampling was used in selecting subjects and proportionate stratified non-random sampling was used in selecting gender for the study.

Instrumentation

The instrument for data collection was Integrated Science Achievement and Retention Test (ISART) developed by the researchers who adopted past questions from Basic Education Certificate Examination (BECE) integrated science. The test covered the four areas – physics, chemistry, agricultural science and biology which sum up to form integrated science in the Ghanaian science syllabus. The test developed by the researchers was from the following topics taught: Basic Electronics (Transistors), Carbon Cycle, Pests and Pesticides and Circulatory System. The ISART was made up of two sections: A and B. Section A was made up of 3 items regarding the Biodata while Section B was made of 30 multiple-choice items with four options per item.

Data Collection Procedure

The process for gathering data for the study lasted for a period of eight weeks. **Week 1** was used in the training of research assistants and administration of pretest questions to the selected subjects. The integrated science teachers in the selected schools acted as the research assistants to teach the instructional packages and administer the instrument to the subjects. The research assistants for the control and experimental groups were given some training by the researchers using prepared lesson plans as training manuals.

Weeks 2-7 were used to provide treatment of instructional packages and the administration of posttest. The instructional package for the treatment involved lessons that were taught to the subjects who were chosen in both experimental and control groups. Both groups had the same content for the instructional package. The only difference is the approach of instruction either by using computer-aided instruction or by traditional method. For the Control group, lessons were delivered by combining lecture and demonstration accompanied with instructional materials to make lesson interesting and meaningful to the students. The students were encouraged to participate in the lesson through questions and comments to avoid boredom. The accomplishment test was given to the two categories as a post-treatment evaluation during the six-week course of treatment in order to calculate their achievement scores. The ISART questions were reshuffled before administering the posttest. **Week 8** was used to administer the post-posttest. Two weeks later, a post-posttest was administered to determine the students' retention abilities.

Data Analysis

The data obtained by ISART was analyzed with respect to each null hypothesis. The data was then classified into pretest, posttest and post posttest for both the control group and experimental group. The stated hypotheses were examined utilizing Analysis of Covariance (ANCOVA) and t-statistics respectively, in Statistical Package for Social Science (SPSS) software version 21 at 0.05 level of significance. Since the study design involved non-randomized, pretest-posttest data, ANCOVA was used as a statistical tool to test the null hypotheses. The pretest scores acted as a covariate to help lower the error variance as well as eliminating systematic bias while the posttest scores were used as the dependent variable

Results

Analysis of covariance (ANCOVA) was employed to investigate the efficacy of the instructional strategies. Preliminary checks were conducted to investigate the assumptions of normality and homogeneity of test scores since these are very important as far as the use of ANCOVA is concerned. Figure 2 is Q-Q Plots showing the normality of the test scores, i.e. pretest and posttest scores. It can be seen from the figure that a linear relationship exists between the dependent variable (posttest) and the covariate (pretest). This means that the two variables are related hence the covariate can be controlled.

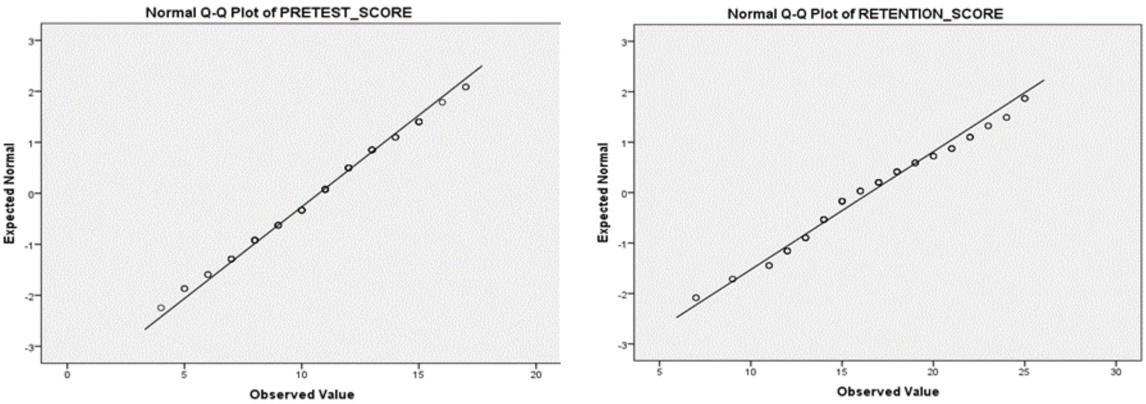

Figure 2: Normality of pretest and posttest scores

The assumption of homogeneity of regression slopes was investigated and the result is presented in Table 2. The interaction term method*pretest is not significant, $p = .594$ which is greater than the .05. This implies that the assumption of homogeneity of regression slopes is not violated.

Table 2: Homogeneity of Regression Slopes

	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	337.444[a]	3	112.481	11.922	.000
Intercept	1089.477	1	1089.477	115.475	.000
Method	37.368	1	37.368	3.961	.050
Pretest	11.384	1	11.384	1.207	.075
Method*pretest	2.705	1	2.705	0287	.594
Error	717.044	76	9.345		
Total	22473.000	80			
Corrected Total	1054.488	79			

a. R Squared = .320 (Adjusted R Squared = .293)

The mean achievement scores of the students based on instructional method

The goal of null hypothesis one was to ascertain if the instructional strategies (treatments) are significantly different of the students' scores on the dependent variable (posttest). The main ANCOVA results are presented in Table 3 below.

[***Table 3: One-Way ANCOVA on Students Posttest Achievement Scores by Teaching Method***

	Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
Corrected Model	334.738[a]	2	167.369	17.905	.000	.317
Intercept	1104.993	1	1104.993	118.214	.000	.606
Pretest	10.726	1	10.726	1.147	.287	.015
Method	330.549	1	330.549	35.363	.000	.315
Error	719.749	77	9.347			
Total	22473.000	80				
Corrected Total	1054.488	79				

a. R Squared = .317 (Adjusted R Squared = .300)

As shown in Table 3, the p-value for the predictor variable (method) is 0.000 (which actually means $p < 0.0005$) which is less than 0.05; therefore, the result is significant. It can be seen that the total variation to be explained (SS_T) was 1054.488 units (corrected total). Results also show that, the amount of variation accounted for (SS_M) by the experimental manipulation was 334.738 (corrected model) units of which the instructional method accounted for 330.549 units, equivalent to 31.5% (eta square). About 719.749 units (SS_R) were unexplained (error).

From the estimated marginal means (shown in Table 4), it is seen that the two instructional methods had different effects. This marginal effect shows how the dependent variables (CAI and TM) changes in terms of student's achievement.

Table 4 Estimated Marginal Means

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Computer aided method	18.400[a]	.484	17.436	19.364
Traditional method	14.325[a]	.484	13.361	15.289

a. Covariates appearing in the model are evaluated at the following values: pretest = 10.74.

It can therefore be concluded that there is a significant difference between the mean posttest achievement scores of students taught with computer-aided instruction and those taught through the traditional approach. The null hypothesis one was therefore rejected.

The mean retention scores of the students based on instructional method
The null hypothesis two was formulated to ascertain if there is a statistically significant difference in the mean retention scores between the students who were taught integrated science using computer aided instruction and those taught using the traditional method. The main ANCOVA results are presented in Table 5 below.

Table 5: One-Way ANCOVA on Students Retention Achievement Scores by Teaching Method

	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	415.905	2	207.952	17.910	.000	.317
Intercept	1493.865	1	1493.865	128.660	.000	.626
Pretest	1.855	1	1.855	.160	.690	.002
Method	408.404	1	408.404	35.174	.000	.314
Error	894.045	77	11.611			
Total	23822.000	80				
Corrected Total	1309.950	79				

As shown in Table 5, the p-value for the predictor variable (instructional method) is 0.000 (which actually means $p < 0.0005$) which is less than the cut-off point 0.05, therefore, the result is significant. It can be seen that the total variation to be explained (SS_T) was 1309.950 units (corrected total). Out of this figure, the amount of variation accounted for (SS_M) by the experimental manipulation was 415.905 (corrected model) units of which the instructional

strategy accounted for 408.404 units, equivalent to 31.4% (eta square). About only 894.045 units (SS_R) were unexplained (error).
From the estimated marginal means (shown in Table 6), it is seen that the two instructional methods had different effects. This marginal effect shows how the dependent variables (CAI and TM) changes in terms of student's retention.

Table 6: Estimated Marginal Means for Students' Retention

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Computer aided method	19.040[a]	.539	17.966	20.114
Traditional method	14.510[a]	.539	13.436	15.584

a. Covariates appearing in the model are evaluated at the following values: pretest = 10.74.

It can therefore be concluded that there is a significant difference between the mean retention achievement scores of students taught with computer aided instruction and those taught through the traditional approach. The null hypothesis which state that there is no statistically significant difference in mean retention scores between students who are taught integrated science using computer aided instruction and those taught using traditional method one was therefore rejected.

Discussion

The study's findings are categorised into two sections: the effect of the treatment on students' integrated science achievement scores and the effect of the treatment on students' integrated science retention scores.

Treatment Effect on Students' Integrated Science Achievement Scores

The study's findings showed a significant achievement gap among the learners of integrated science that received CAI compared to those who received lectures. This demonstrates that the average academic performances of the experimental and control groups statistically differ. Because the estimated effect size of the ANCOVA test (Table 3) was declared significant, the experimental group exposed to CAI outperformed the control group taught using the traditional approach. Simply put, there are significant disparities in achievement between students who are taught with CAI as compared with the traditional method. Thus, students who were taught using CAI did better on integrated science concepts than students who were taught using lecture approaches. This finding is in line with Mohammed (2014) who found that learners who utilized CAI outperformed those that used the conventional technique in terms of integrated science concepts and computing. The findings also corroborate those of Ada, Anyachebelu, & Chinyelu, (2012), who discovered and reported a substantial difference in the performance of students taught by CAI and traditional method.

The use of computer-aided instruction, which inspires interest, enthusiasm, total involvement in the teaching and learning process, and encourages students to work at their own pace, could be the cause for the experimental method's improved achievement (Egbodo, 2016). The study's findings suggest that appropriate instructional strategies, such as CAI should be used and developed in order to improve meaningful teaching and learning in basic science. Results of the research, on the other hand, contradict those of Imhanlahimi and Imhanlahimi (2008), who found no significant difference in final test results between CAI students and traditional teaching style students. Augustinah and Bolajoko (2014) findings on comparative forms of instruction with CAI modes revealed that CAI is not as useful as previously thought, as pupils in the CAI group did not outperform those in traditional modes of instruction. In contrast to these studies (Augustinah & Bolajoko, 2014; E. O. Imhanlahimi & R. E. Imhanlahimi, 2008)**,** the current study has shown that the usage of CAI was effective to produce significant results. The improved student performance may be a result of CAI providing more concrete representations of ideas and concepts that were normally taught abstractly in regular traditional classes.

Treatment Effect on Students' Integrated Science Retention Scores

The results in Table 5 show that students who received computer-assisted training remembered and recalled basic science concepts better than those who received traditional instruction. The CAI has proven to be a major determinant in students' recall abilities in basic science, as shown Table 6. It appears that, CAI is among the most effective ways for the teaching of integrated science to Ghanaian pupils. There was a substantial difference in retention ratings between students who received basic scientific instruction utilizing CAI compared to those who received instruction by the usage of conventional approach. Mohammed (2014), and Orisebiyi (2007) discovered a significant contrast among learners taught using CAI with respect to learners that were taught using conventional teaching approaches in terms of retention ratings, with the learners in CAI group performing better than the conventional group learners.

Furthermore, the findings of the current study are consistent with other studies (Kareem, 2015; Ndanwu, & Ezejiofor, 2021)) found that CAI was effective in increasing achievement and retention of students. The authors found that computer-assisted instruction could maintain students' interest, motivate them to participate actively in the session, and assist them in remembering the information learned for a long period. In science education, computer-assisted instruction that employs the ideas of explaining and seeing on the screen to motivate and elicit positive responses from students may increase meaningful learning, achievement, and retention.

Conclusion and Recommendation

Based on the findings of this research, it was concluded that the use of computer-aided instruction in the learning of integrated science enhances achievement of the junior high pupils. The use of computer-aided instruction in the learning of integrated science was also discovered to have enhanced retention of the junior high pupils. This means the retrieving power of pupils are increased when CAI is used in the learning of integrated science more than when the traditional method is used. The study found that incorporating appropriate media (e.g. CAI) into classroom teaching and learning to complement conventional approaches is likely to result in better learning outcomes. CAI-taught JHS students performed better than traditionally-taught students. The use of CAI in the teaching and learning of integrated science has significantly improved performance and retention.

Based on the findings, Government, Non-Governmental Organizations and Parents-Teacher Associations are urged to fund the development of CAI packages for junior high schools, equip them with necessary ICT facilities and train manpower to produce software for science teaching and learning in Ghanaian basic schools. Schools should also train science teachers on the use of ICT resources for science teaching and learning particularly, the use of different software packages, DVDs, videotapes, overhead projectors on science concepts and processes to encourage the potentials of ICT in the junior high schools.

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