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Effect of Process-Based, Project-Based and Expository Instructional Approaches on Senior Secondary Chemistry Students' Retention in Akamkpa Local Government Area, Nigeria

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Abstract

This study examined the effects of Process-Based, Project-Based, and Expository instructional approaches on Chemistry students' retention in Akamkpa LGA, Cross River State. A pretest posttest, non-randomized, non-equivalent control group quasi-experimental design was used. Three research questions and hypotheses guided the study. The population comprised all SS II students in 16 public co-educational secondary schools, with a sample of 158 students selected from three schools through simple random sampling. A Chemistry Retention Test (CRT), validated by experts in Measurement and Evaluation and Chemistry, served as the instrument. Reliability testing using Pearson Product Moment Correlation yielded a coefficient of 0.74. Data were analyzed using mean, standard deviation, and ANCOVA at a 0.05 significance level. Findings revealed that Process-Based instruction produced the highest retention levels, outperforming Project-Based and Expository methods. Gender differences were significant, with male students showing higher retention. The study recommends Process-Based instruction to enhance participation and retention.

Keywords: Process-Based, Project-Based, Expository and Retention

Introduction

Science Education play important role in the scientific and technological development of any nation. It equips learners with the knowledge, skills and attitudes needed to understand natural phenomena and solve real-life problems. Science Education lays the foundation for technological advancement, developing people's way of life, interaction and innovation to bring about establishments of healthy environment and healthy living (Koffi, 2021). Science teaching and learning focus on sharing science contents and processes to provide opportunities for students to interact with their environment and acquire basic science skills (Williams, 2023). Among the various branches of Science that contribute significantly to scientific and technological development. Chemistry occupies a central position in explaining the composition, properties and transformation of matter.

Chemistry is the branch of science concerned with the substances of which matter is composed, the investigation of their properties and reactions form new substances. Chemistry is one of the science subjects taught at the senior secondary level of secondary schools. It is important that students acquire knowledge and mastery of the concepts taught as embedded in the chemistry curriculum. To achieved this Chemistry teacher are to guide students through the use of appropriate instructional strategies that can help them. One of the concepts taught and learnt in chemistry is Esterification.

Esterification is the chemical reaction that takes place for the formation of esters. It is the process of combining an organic acid (R-COOH) with an alcohol (R`-OH) to form an ester (R-COO-R`) and water (H_2O). Brises (2021) described esterification as a chemical reaction between an alcohol and acids which results in the formation of an ester. The esterification mechanism takes place when carbocation (or a positively charged carbon) is formed in the acid molecule and interacts with the oxygen atom in the alcohol. This complex then transfers the proton from the alcohol to another proton acceptor to act as a leaving group, leaving an 'OR' group where there was once a hydroxyl (OH) group.

Ogundoro and Atolani (2022) referred to esterification as a fundamental organic reaction involved in the synthesis of esters, usually occurring through the reaction between carboxylic acids and alcohols in the presence of catalysts. A reaction involving combination of salicyclic acid and acetic acid forms acetylsalicyclic acid (a drug called Aspirin) and is an esterification process. Liu *et al.*, (2023) also stated that ester may also be obtained through esterification process involving reaction of acid halides or acid anhydrides with alcohol, carboxylic acid or a third ester in the presence of a catalyst. Approaches that are learner-friendly like Process-based and project-based approaches can enhance and motivate students' interest towards learning and understanding Esterification. Esterification is important as it produces stable, versatile compounds needed for flavours, plastics, biofuels and pharmaceutical industries. They play vital roles as plasticizers, solvent, lubricants and polyester fabrics and surfactants (soaps and detergents) for industrial applications. It enables better solubility, viscosity and stability in food containing starch. To retain the concept of esterification, students are to be taught using appropriate instructional approaches. One of the instructional approaches that can be used to achieve this is Process-Based instructional approach.

Learners have shown significant deficiency in knowledge of esterification, a challenge traceable to lack of proper understanding of the concept. Despite the fundamental importance of esterification in everyday applications ranging from food flavorings to pharmaceutical synthesis many senior secondary students in the Akamkpa Local Government Area (LGA) of Cross River State consistently demonstrate poor long-term retention of the concept. This inability to maintain a grasp of the concept is clearly reflected in both internal school evaluations and external standardized examinations like West African Examination Council (WAEC) and National Examination Council (NECO). Consequently, students are often unable to recall or apply the core principles of esterification once the immediate examination period has passed. While learner-centered approaches specifically the Process-Based and Project-Based approaches have gained recognition in science education for their potential to enhance engagement and knowledge durability, empirical data comparing their specific impact on memory retention remains scarce. Therefore, this study investigates the effects of Process-Based and Project-Based instructional approaches on students' retention of esterification in Akamkpa Local Government Area.

Process-Based instructional approach specifies targeted teaching objectives. It is a student-centered approach that helps students know where the process will go, the pace and the direction of the learning. Process-based instructional approach gives the learner the opportunity to explore their learning by obtaining information and transforming it into knowledge to acquire basic science skills (Marzano, 2021). Process-Based approach defines and describes specific steps, activities and sequence involved in a particular problem situation. It is a representation of several processes showing the stages in which an individual has to progress or follow to arrive at the expected end. It comprises organized steps and method of reasoning to bridge the gap between the problem and the result (Buck-Sorlin, 2023). Levi (2020) defined Process-Based approach as a teaching-thinking domain-specific-knowledge aimed at understanding concept. The role of the teacher is to activate students' mental ability through cognitive coaching and guide learning. Imray *et al.*, (2020) posits Process-based instructional approach is holistic in its presentation of teaching concepts to become the objective. Teacher stimulates students through thinking and applying what they think to understand the sequence and interactions of processes to solve problem. The students participate by trying to link one process to another to obtain the sequence. This approach helps students to develop critical thinking, problem-solving skills and a better understanding of scientific concepts through active participation in the learning process. Ahmad (2022) investigated the impact of Process-Based instructional approaches on students' retention in hydrocarbon concepts in Senior secondary schools in Ondo state and it was found that the use of instructional approaches like Process-Based instructional approaches significantly improves students' retention in chemistry. Samuel *et. al.*, (2023) carried out a study on the impact of Process-Based Instruction (PBI) approach on secondary school students' academic retention in Science. Although Process-Based instructional approach has been recommended for improving students' understanding of Chemistry concepts, few studies have examined its effect on students' retention in esterification. This necessitates further investigation into the approach. Beyond the Process-Based approach another learner-centred approach that encourages active engagement and practical application of knowledge is the Project-Based instructional approach.

Project-Based instructional approach involves students designing, developing and constructing hands-on solutions to a problem. It is a style of active learning and inquiry-based learning which contrast paper-based, rote memorization and teacher-led instruction to present established facts that portrays a smooth path to knowledge instead of posing questions, problems and bringing up scenarios (Bender, 2021). It aims at building students' creative capacity to work through difficult or ill-structured problems, commonly done in small teams **(**Naseer 2025). In the teaching of Esterification, students are able to relate classroom learning to real-life experiences through investigations and practical activities. Okoye and Osuafor (2021) investigated the effects of Project-Based instructional approach on students' retention of science process skills in Awka Education Zone of Anambra State and found that students' taught using Project-Based approach retained scientific concepts better than those taught using conventional methods. Adebisi *et al.,* (2021) investigated the effects of Project-Based learning on students' retention in Biology among Senior Secondary School students in Afijio Local Government Area of Oyo State, Nigeria. A pre-test, post-test control group quasi-experimental design was employed. The population consisted of all SS II Biology students in the area. Simple random sampling technique was used to select a sample of 80 students from selected schools. The instrument used for data collection was Biology Retention Test (BRT). A reliability coefficient of 0.81 was obtained using Kuder–Richardson formular. Mean and standard deviation were used to answer research questions, while ANCOVA and t-test were used to test hypotheses at 0.05 level of significance. The findings revealed that students exposed to Project-Based learning had significantly higher retention than those taught using traditional teaching methods. To the best of the researchers knowledge, no work have been carried out in Chemistry on Project-Based and Process-Based instructional approaches in Akamkpa Local Government Area, therefore this work intends to fill the gap.

Learners often require structured guidance and clear explanations for effective understanding of concepts, attention must also be given to the Expository approach which provides systematic explanations. Ekpo and Ogar (2022) investigated the effects of expository approach on students' retention in Basic Science and Technology among junior secondary school students in Yala, Cross River State, Nigeria. A pre-test, post-test non-randomized control group quasi-experimental design was employed. The target population consisted of 3,546 JSS students, while intact class sampling technique was used to select a sample of 100 students from two co-educational secondary schools. The instrument used for data collection was Basic Science and Technology Retention Test (BSTRT). A reliability coefficient of 0.78 was obtained using Pearson Product Moment Correlation. Mean and standard deviation were used to answer research questions, while analysis of covariance (ANCOVA) was used to test hypotheses at 0.05 level of significance. The findings revealed that students taught using expository approach retained knowledge below average.

Effects of expository instructional approach on students' retention in Physics among senior secondary school students in Ikot Abasi Local Government Area, Akwa Ibom State, Nigeria was carried out by Inyang *et al.,* (2023). A pre-test, post-test quasi-experimental design was employed. The target population consisted of SS II Physics students, while a sample of 120 students was selected using intact class sampling technique. The instrument used for data collection was Physics Retention Test (PRT). A reliability coefficient of 0.82 was obtained using Kuder–Richardson 20. Mean and standard deviation were used to answer research questions, while ANCOVA was used to test hypotheses at 0.05 level of significance. The results showed that students taught using expository strategy performed better in theoretical concepts. The works above were carried out in Physics and Basic Science, therefore this study will fill the gap in Chemistry as a subject. The researchers carried out works on different instructional approaches and retention but not on Project-Based instructional approaches which this work will cover that gap.

Gender is defined as the differences existing between a man and a woman based on strength, mental ability and behavioural characteristics. Gender is concerned in learning especially when it involves science learning. Barr et al. (2023) defined gender as a multidimensional construct that encompasses multiple domains including identity and expression, roles and norms, relations, and power. Nwoku (2022) investigated on gender effects on science students' retention in Basic Science and found that male students were actively involved in the lesson and that led to them acquiring more scientific skills than the female counterparts. Eze, *et al.,* (2025) investigated the efficacy of context-based instructional approach of teaching chemistry on Male and Female students'

retention in Agbani Education Zone and found out that female exhibited higher retention than the male students. Mkpanang and Sam (2025) Examined gender differences in retention of simple harmonic motion through technology-enhanced guided-inquiry among physics students. findings showed that both male and female cohorts encoded and retrieved the physics concepts with equal cognitive efficacy.

The empirical studies above, shows previous research work carried out in Process-Based, Project-Based, Expository approaches and students' retention in science. In each study carried out by past researchers, none was carried out in Chemistry and Akamkpa Local Government Area which this work will fill the gap.

Research Questions

The following research questions guided the study;

1. What is the difference in the mean retention scores among students taught Chemistry using Process-Based, Project-Based and Expository instructional approaches respectively?
2. What is the difference in the retention mean scores among male and female students taught Chemistry using Process-Based, Project-Based and Expository instructional approaches respectively?

Research Hypotheses

The following research hypotheses were raised to guide the study

1. There is no significant difference in the mean retention scores among students taught Chemistry using Process-Based, Project-Based and Expository instructional approaches respectively.
2. There is no significant difference in the retention mean scores among male and female students taught Chemistry using Process-Based, Project-Based and Expository instructional approaches respectively.
3. There is no significant interaction effect of the treatment groups and gender on retention of students taught Chemistry

Methodology

The research design adopted for the study was a quasi-experimental design, specifically, the pre-test, post-test only non-randomized group design. This design was adopted because it allows the use of intact classes and also for the manipulation of independent variables to observe effects on dependent variable. The population of study comprised all senior secondary two (SS II) students in all the 16 public co-educational Secondary Schools in Akamkpa Local Government Area of the 2025/2026 academic session. The sample size was 158 senior secondary two (SS II) students from the public secondary schools selected using Simple Random Sampling technique. Out of 158 sample drawn, 69 were males and 89 were females. Intact classes were randomly assigned to the experimental and control groups. Experimental group one (E_1) was taught using Process-Based instructional approach and the Experimental group two (E_2) was taught using Project-Based instructional approach and the Experimental group three (E_3) was taught using Expository instructional approach. The instrument for the study was the Chemistry Retention Test (CRT). It had two (2) sections: sections A and B. Section A carrying the personal information while section B contained 30 question items extracted from West African Examination Council (WAEC) from 1990-2025 past questions papers.

The instrument was content by giving to 5 students outside the sample population and face validated by three experts; one from the Test and Measurement unit of the Department of Psychological Foundations, one from the Department of Chemistry; Faculty of Science and one from Department of Science Education. To ascertain the reliability of the instrument, twenty (30) multiple-choice test items were trial tested on 30 students who did not form part of the study but had the same characteristics as those used for the study. The reliability of the instrument was determined using the test–retest method. The instrument was administered twice to the same group of respondents at a two-week interval, and the scores obtained were correlated using the Pearson Product Moment Correlation (PPMC) Coefficient to obtain the reliability coefficient of 0.74.

Research Procedure

The sampled schools were selected using simple random sampling technique. Before the commencement of the treatment, the instrument were administered as pre-test with the help of research assistants, scripts were collected, marked and scored by the researchers. The students in experimental group one and two were taught using Process-Based and Project-Based instructional approaches respectively. Students in the control group were taught using expository instructional approach. All in their intact classes. The

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teaching in the three groups were done during normal class period for Chemistry and in intact class to avoid disrupting the school programme. Three weeks after, posttest of the Chemistry Achievement Test (CAT) was reshuffled and re-administered as Chemistry Retention Test (CRT). Test scripts from the retention test administered was collected immediately at the end of each test by the research assistants and submitted to the researcher. Data collected were analysed using mean and standard deviation to answer research questions and Analysis of Covariance (ANCOVA) to test the null hypotheses. The decision to accept or reject the stated null hypotheses was with reference to the p-value. If the calculated p-value for F-ratio was lower than 0.05 alpha level of significance, the hypothesis was rejected but if the calculated p-value for F-ratio was higher than 0.05 alpha level of significance, the hypothesis was retained.

Results of Data Analysis

Table 1: Mean and Standard Deviation Scores of Posttest Scores and Retention Classified by Instructional Approaches

Groups	N	Posttest Mean	S.D	Retention test Mean	SD	Mean Loss Gain Score
Process-based	56	52.29	3.52	45.36	1.46	-6.93
Project-based	52	42.17	3.21	37.44	1.98	-4.73
Expository	50	35.84	2.84	32.51	1.73	-3.33

Data in Table 1 shows the retention and post-test mean scores and standard deviation of the three groups (Experimental Group 1, Experimental group 2 and Experimental group3) of students taught Chemistry using Process-Based, Project-Based and Expository instructional approaches respectively. The post-test and retention mean scores of 52.29 and 45.36 respectively, students in the Process-Based group yielded the best retention of -6.93. This is followed by the Project-Based group with post-test and retention mean scores of 42.17 and 37.44 respectively, resulting in a mean of -4.73. Students in the Expository group recorded post-test and retention mean scores of 35.84 and 32.51 respectively, yielding a mean loss of -3.33. The result indicates that students taught esterification using the Process-Based instructional approach performed better than those taught using Project-Based and expository approaches.

Hypothesis one

Table 2: Summary of Analysis of Covariance (ANCOVA) of Students' Retention Scores Classified by Treatment Groups with Posttest Scores as Covariate

Source	Sum of Squares	Df	Mean Square	F-Value	P-Value
Corrected Model	6039.837	3	2013.279	678.920	.000^{S}
Intercept	1124.807	1	1124.807	379.309	.000^{S}
Posttest Scores	1.231	1	1.231	.415	.520^{NS}
Instructional Approaches	1022.469	2	511.234	172.399	.000^{S}
Error	521.913	155	2.965		
Total	141863.000	158			
Corrected Total	6561.750	157			

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Data in Table 3 shows that, the calculated F-ratio for the effect of instructional approaches at df 2, 158 is 172.399 while its corresponding calculated level of significance is .000. Since the calculated level of significance is less than .05 in which the decision is based, this indicates that there is a significant difference in the retention mean scores of Chemistry students taught the concept of esterification using Process-Based, Project-Based and Expository instructional approaches respectively. With this observation, null hypothesis 1 was rejected. The direction of significance was determined using Scheffe post hoc in Table 3 below.

Table 3: Scheffe Post Hoc Tests for Retention-test Classified by Treatment Groups

(I) Instructional approaches	(J) Instructional approaches	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Process-based	Project-based	6.609*	.518	.000	5.587	7.632
	Expository	13.628*	.758	.000	12.133	15.123
Project-based	Process-based	-6.609*	.518	.000	-7.632	-5.587
	Expository	7.019*	.422	.000	6.185	7.852
Expository	Process-based	-13.628*	.758	.000	-15.123	-12.133
	Project-based	-7.019*	.422	.000	-7.852	-6.185

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

The results in Table 3 shows the mean differences in retention between students taught using Process-Based and Expository instructional approaches was (-7.019; Sig=.000), Process-Based and Expository instructional approach was (-13.628; Sig=.000); Process-Based and Project-Based instructional approach was (-6.609; Sig=.000) at 0.05 alpha level. This implies that those taught using Process-Based instructional approaches retained significantly better compared with those taught using Project-Based and those taught using Expository instructional approaches. Those in the Expository approach group had the least retention scores.

Table 4: Summary of Mean and Standard Deviation of Post-test and Retention Scores of Male and Female Students taught using Process-based, Project-based and Expository Strategies Respectively

Instructional Strategies	Gender	N	Post-test	SD	Retention-test	SD	Mean Loss
Process-based	Male	26	60.17	14.45	46.37	11.35	-13.80
	Female	30	52.68	10.82	41.38	9.26	-11.30
Project-based	Male	20	31.84	2.77	23.51	2.37	-8.33
	Female	32	36.33	3.93	29.74	2.13	-6.59
Expository	Male	23	25.40	2.46	21.42	2.06	-3.98
	Female	27	25.23	2.69	20.13	1.48	-5.10

Data in Table 4 shows that the mean loss for scores of male students taught using Process-based learning approach is -13.80 and their female counterparts is -11.30. The mean loss for male students taught using Project-Based learning approach is -8.33 and their female counterparts is -6.59. The table also showed that the mean loss of male students taught using Expository approach is -3.98 and their female counterparts is -5.10. It can be inferred from the results that male students had higher retention score than their female counterparts when taught using Process-Based and Project-Based approaches whereas female students

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retained the concept better than their male counterparts when taught the concept of Esterification using Expository strategy.

Table 5: Summary of Analysis of Covariance (ANCOVA) of Male and Female Students' Retention-test Scores Classified by Treatment Groups and Gender with Post-test Scores as Covariate

Source	Type III Sum of Squares	Df	Mean Square	F-value	P-value
Corrected Model	2234.463	5	446.893	176.504	.000^{S}
Intercept	1303.330	1	1303.330	514.762	.000^{S}
Covariate (Post-test Scores)	5.236	1	5.236	2.068	.152^{NS}
Main Effect (Instructional Approaches)	2170.455	2	1085.228	428.621	.000^{S}
Main Effect (Gender)	3.702	1	3.702	.510	.000^{S}
Approaches * Gender	2.220	1	2.220	.877	.350^{NS}
Error	440.552	155	2.532		
Total	5364.000	158			
Corrected Total	3210.765	157			

R Squared =. 415 (Adjusted R Squared =.387) S = Significant at p<. 0.05 Alpha Level.

Data in Table 5 shows the calculated F-value for the main effect of gender on students' retention (F=172.399; Sig=.000). Since the corresponding level of significance is less than 0.00, it therefore implies that there is a significant difference between mean retention scores of male and female students taught in the three groups (Process-Based, Project-Based and Expository approaches). The hypothesis is rejected. This implies that male students retained the concept better than their female counterparts when taught using Process-Based learning approach; the females retained the concept better than their male counterparts when taught using Project-Based instructional approach while the males and females were at the same retention level when taught using Expository approach.

Table 6: Summary of ANCOVA for Students Retention Scores Classified by Treatment Groups and Gender with Posttest Scores as Covariate

Source	Sum of Squares	Df	Mean Square	F-value	Sig.
Corrected Model	13645.772	5	2729.159	29.541	.000^{S}
Intercept	2416.621	1	2416.621	31.38	.000^{S}
Posttest Scores	13.852	1	13.852	0.011	.921^{NS}
Instructional Approaches	5389.311	2	2694.655	42.492	.000^{S}
Gender	143.151	1	143.151	1.921	.18^{NS}
Instructional Approaches * Gender	332.334	2	166.167	1.772	.001^{S}
Error	9742.793	155	62.856		
Total	59894.000	158			
Corrected Total	20788.736	157			

R Squared =. 54 (Adjusted R Squared =.52) S = Significant at p<. 0.05 Alpha Level.

Data in Table 6 shows that the calculated F-ratio for the interaction effect of treatment groups and gender at df of 2, 158 is 1.77 while its corresponding level of significance is 0.05. The level of significance is less than 0.05 alpha level of significance on which the decision is based; it therefore indicates that there is a significant interaction effect between instructional approaches and gender on students' retention. Thus, the hypothesis is rejected. This implies that interaction of

different instructional approaches and gender have significant effect on students' retention.

Discussion of the Findings

Findings on the difference among the retention mean scores showed that students taught esterification using Process-Based learning approaches had higher retention as compared with those taught using Project-Based and those taught using Expository approaches. This may be because students taught esterification using Process-Based Instructional approaches had a deeper understanding of the concept as they followed the processes that guided them during the learning process than those using Project-Based and Expository Instructional Approaches. This aligns with Kenter (2021) results that there is significant difference in the retention level of students taught using Process based and concept mapping approaches and those taught using expository approach as these set of students had higher mean retention gain, suggesting that they achieved greater retention than those taught using expository approach. Findings also agrees with Ekundayo (2023) findings that the use of innovative instructional approaches significantly improves students' retention in Chemistry compared to expository approaches. According to the author, interactive and student-centred approaches enable learners to actively construct knowledge, thereby improving their long term retention of scientific concepts.

Findings on the difference in the retention mean scores between male and female students taught esterification using Process-based, Project-based and expository approaches showed that there is a significant difference between the retention scores of male and female students across the three approaches (Project based, Project based and Expository) approaches. This may be due to the fact that the male students had a deeper understanding of the concept learnt and were able to retain the knowledge in their memory store and retrieve it when there was need to recall than their female counterparts. These findings agree with Nwafor (2025) who reported that gender differences can influence students' retention of science concepts, particularly when students are exposed to learner-centred instructional approaches. These also aligns with Ojelade, *et al.*,(2024) findings that gender significantly influenced students' retention in Chemistry when innovative instructional approaches were employed. According to the authors, differences in learning styles, participation levels and classroom engagement may contribute to variation in retention between male and female students.

Findings on the difference in the retention mean scores between male and female students taught Esterification using Process-based, Project-based and Expository approaches indicated that there is a significant interaction effect of instructional approaches and gender on retention. This may be due to the different instructional approaches students in the different groups were exposed to bringing about variation in the level of retention of the concept by students in the different groups. The findings agree with Ndukwe and Mumuni (2021) that instructional approaches significantly enhance students' retention in Chemistry, emphasizing the importance of instructional approaches in long term learning. It also aligns with Egara and Mosimege (2023) that there is a significant interaction effect of instructional approaches and gender on students' retention on Algebra.

Conclusion

From the findings, it was concluded that students taught Esterification using Process-Based instructional approach retained better than those taught using Project-Based and Expository instructional approaches. Based on gender, it was observed that male students retained better than female students and there is a significant interaction effect of instructional approaches and gender on Chemistry students' retention when taught Esterification.

Recommendations

From the study, the following recommendations were made:

1. Students should ensure they are actively involved in class activities to enhance mastery of concepts learnt.
2. Chemistry teachers should ensure the utilization of suitable instructional approach that would enhance Students full participation during the learning process.
3. School Administration should organize seminars regularly for Chemistry teachers to educate them on the need to use and how to use suitable instructional approaches for the teaching of topics in Chemistry.

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