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Assessing the Effectiveness of Case-Based Learning on Students' Attitudes Toward Chemistry and Formal Reasoning in Acid-Base Topics

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Abstract

Effective teaching strategies are critical in enhancing students' attitudes toward chemistry and formal reasoning abilities, particularly for complex topics like acids and bases. Case-based learning has emerged as a promising alternative to traditional scientific learning methods. This study aims to compare the differences in attitudes toward chemistry and formal reasoning skills between students exposed to case-based learning and those undergoing scientific learning on acids and bases. A quasi-experimental design with a posttest-only control group was applied to 122 student of 11th grade science students in Yogyakarta, selected using simple random sampling. Data were collected through case-based essay questions and attitude questionnaires. Multivariate analysis (Hotelling's Trace) assessed the differences between groups. The analysis revealed a significant difference ($p = 0.000 < 0.05$) in attitudes and formal reasoning skills between the two groups. Students in the case-based learning group demonstrated significantly better attitudes toward chemistry compared to those in the scientific learning group. These findings highlight the potential of case-based learning to enhance students' engagement and reasoning skills in chemistry. By integrating case-based approaches into acid-base learning, teachers can adopt alternative methods to improve student outcomes. This study underscores the importance of diversifying teaching strategies to address the challenges of complex scientific topics effectively.

Keywords: acid-base, attitudes towards chemistry, case-based learning, students' formal reasoning

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1. Introduction

The development of the world in the 21st century requires students to be able to compete with other students, without being isolated in the geographical boundaries of the country. The success of a student depends on himself and the fulfillment of 21st century skills, so students are required to learn to have them (Lai & Hsu, 2022). The partnership for 21st Century Skills identifies 21st century skills that include critical thinking, problem solving, communication and collaboration. Learning that reflects one of the 21st century skills is learning that refers to students' activeness in analyzing and compiling their own understanding based on their experience and knowledge or high order thinking. However, based on the results of the Program for International Program Assessment (PISA) in 2018 according to the Organization for Economic Cooperation Development (OECD), Indonesia ranked at the bottom, they are; 71, 74 and 73 in science, reading and mathematics skills out of 79 countries (Schleicher, et al., 2019). Indonesia's low ranking in PISA 2018 can be caused by teaching focusing on aspects of remembering rather than understanding, students are more dominant in listening to material than being active in learning and the lack of application of learning materials to student culture so that students are unable to think reasoning (Dewi et al., 2019).

In the context of chemistry learning, formal reasoning is particularly crucial because chemistry, as a science, involves many abstract concepts that require systematic and logical analysis for problem-solving. Beyond mastering basic theories such as the law of conservation of mass, chemical reactions, or acid-base concepts, students need to develop the ability to connect these principles in more complex situations. For example, when solving stoichiometry problems or determining the pH of a solution, students must think logically, apply formulas, and analyze experimental data to draw accurate conclusions. Formal reasoning in chemistry also aids students in constructing strong scientific arguments based on empirical evidence, rather than relying solely on rote memorization of formulas or facts (Bodner & McMillen, 2020; Lawson & Worsnop, 2022). Therefore, it is essential to adopt teaching approaches that develop critical thinking skills through case-based learning. Providing students with real-world cases or chemical experiment simulations that require data analysis and theoretical understanding can strengthen their formal reasoning skills.

Through this approach, students are trained to analyze experimental data, identify patterns, and solve problems using a systematic scientific approach. As Bagdasarov et al. (2022) argued, learning is more effective for students when using well-structured cases, which offer them opportunities to practice logical thinking, ultimately enhancing their understanding of chemical concepts and their ability to solve more complex chemistry problems. This aligns with Fowler & Patel (2021) findings, which show that improving students' formal reasoning skills correlates with progress in understanding science content, including chemistry, as it becomes increasingly complex.

In the learning process approach, learning is a starting point or point of view on the learning process and serves as a guide for learning designers and teachers in planning teaching and learning activities (Slavin, 2018). The learning model in the 2013 curriculum is oriented towards the scientific approach. According to Savery (2015) learning must be interesting and fun and able to activate students to solve a problem. The failure to achieve learning objectives is influenced by several factors, one of which is the mistake in choosing a learning model or learning approach. The learning applied by the teacher is only teacher centered, the teacher only provides material and directs students to record the material provided, then students discuss without fostering the scientific process in it (Holme, 2015).

Case-based learning is one of the approaches that can train students in solving a problem. Case-based learning is able to emphasize students' ideas then discuss various real-life problems and students can share ideas and knowledge with their peers so that students become active in the learning process. The case-based learning process is an active and independent learning process (Khan et al., 2015). Case-based learning is consistent with the constructivist theory approach (Koballa & Tippins, 2017) because students are able to actively participate and construct their own knowledge in this method. The character of this case is the result of what students think will depend on the student's thinking process so that students are able to express the results of their thoughts through reasoning and in line with science education that emphasizes students to build knowledge that involves students must be active in a realistic and social learning environment and not just receive knowledge from the teacher (Barron & Darling, 2018).

Schools with less superior student input will be a problem of unfamiliarity with chemistry lessons and will find it difficult to solve a problem in chemistry material. Therefore, topics in chemistry learning that relate abstract concepts that are difficult for students to understand such as acid-base material, then case-based learning is able to help make it more concrete (Belford & Herreid, 2013). This case has a lot to do with acid-base and is often encountered in everyday life such as acid-base balance disorders used in this case are disorders of the stomach such as ulcer disease (gastritis), dyspepsia, Gasttroesophageal Reflux Disease (GERD) and also Acid Rain so it is suitable in overcoming student learning weaknesses, especially in chemistry learning. Case-based acid-base learning was conducted to see the attitude towards chemistry and also students' formal reasoning.

On the other hand, in the current era, the world faces environmental challenges where future students lose interest in science subjects such as chemistry (Wan & Mat, 2018). Slameto (2010) states that to achieve good learning results, students must have an attitude towards the material they learn. If the subject matter is not of concern to students, boredom will arise so that it has an impact on their reluctance to learn. Attitude towards chemistry is a reaction or response that arises from students towards chemistry which then leads to student behavior towards these lessons in certain ways. Previous research has proven that students have different attitudes towards each of the different science points such as chemistry, physics, and biology lessons (Rutjens, 2018).

2. Research Method

2.1. Research Design

This type of research is quantitative research with a quasi-experimental design using the Posttest only control group design method using two classes, they are the control class and the experimental class. The experimental class is a class that is given treatment in the form of a case-based learning (cBL) approach, while the control class is not given special treatment, meaning that it applies the learning that has been done at school, using a scientific approach. The research design can be seen in Table 1.

Table 1. Research Design

Group	Treatment	Post-test
Experiment	X_1A	Q_1y_1
Control	X_2	Q_2y_1

*X_1 (Case-based acid base learning (cBL)); Y_1 (Students' Formal Reasoning ability test after treatment); X_2 (Acid-Base learning using the scientific approach); Q_1 (Attitude toward Chemistry Scale); A (Observation of student activity on cBL and its implementation).

2.2. Sampling

The sample in this study used a simple random sampling technique involving 122 high school students from the 11th grade of Natural Sciences in one of the high schools in Yogyakarta. Consisting of 60 students who were experimental classes (given treatment in the form of a case-based learning approach (cBL)), while 62 students for the control class who were not given special treatment.

2.3. Data Collection Technique

There are two case-based acid-base learning implementation plans: in the experimental class, learning is conducted using the characteristics of a case-based learning approach, while in the control class, a scientific approach is applied. Both approaches are adjusted to the number of meetings on acid-base material, consisting of four sessions. The first meeting covers the concept of acids and bases, the second meeting focuses on acid-base indicators, the third meeting involves an acid-base indicator practicum, and the fourth meeting discusses the degree of acidity of acids and bases. Furthermore, the research instruments used include tests and non-tests. The test instrument consists of case-based questions presented as descriptions with indicators developed by Lawson (2022) to observe the tendencies in students' informal reasoning patterns between control and experimental class groups subjected to different treatments (Mahdi, 2014).

2.4. Data Analysis Technique

2.4.1. Validity and Reliability Test

All of the instruments made must be through validation test and rehabilitation before being used in the research. The validation tests validation theory and empiric. Theoretical validation was carried out by means of expert judgment on learning devices, case questions in the form of descriptions, and student chemical attitude questionnaires. The results of theoretical validation in the form of qualitative data in the form of suggestions or input on the description case questions and questionnaires. Suggestions given by expert judgment are used as the basis for improving learning devices, case questions in the form of descriptions, and questionnaires of attitudes towards student chemistry. Validation theory is used to determine whether the product to be developed has good content or not (Aiken, 1999).

After the revision, the next step is empirical validation by conducting a test of the description case question and the chemistry attitude questionnaire to students who are not the research sample. Empirical test of the description case question and attitude questionnaire towards student chemistry in the form of posttest only with 60 students as respondents. The results of the empirical test were carried out using the Rasch model Quest program.

In this study, the reliability of the attitude towards chemistry questionnaire instrument and formal reasoning test was analyzed using Cronbach's Alpha analysis. Cronbach's Alpha value is calculated with SPSS software version 26 by looking at the reliability criteria based on the Cronbach's alpha coefficient value. Cronbach's alpha coefficient value criteria can be seen in Table 2 (Hair, et al., 2010).

Table 2. Cronbach's Alpha Coefficient Values

Value of reliability coefficient Cronbach's alpha	Reliability Level
0,00 – 0,20	Less reliable
>0,20 – 0,40	Rather reliable
>0,40 – 0,60	Quite reliable
>0,60 – 0,80	Reliable

2.4.2. Research Data Analysis

The data analysis technique used in Hotelling's T^2 test was carried out with the help of SPSS 16.0. The analysis can be done to meet the need of nine pre-qualification assumption tests of MANOVA, which are (1) the independent variable consists of two or more independent groups; (2) The dependent variable must be measured at the interval or ratio level; (3) there is no relationship between observers within each group or between groups; (4) an adequate sample size of at least 25; (5) no univariate or multivariate outliers; (6) there is multivariate normality; (7) there is a linear relationship between each pair of dependent variables for each independent variable; (8) there is homogeneity can be seen from the Box's M test; and (9) there is no multicollinearity by looking at the Tolerance and VIF values, if the Tolerance value > 0.10 and VIF < 10, then the data is free from multicollinearity symptoms.

2.4.2.1. Multivariate Test

The multivariate test used is Hotelling's T^2 test. Hotelling's T^2 test was used to analyze the difference between attitude towards chemistry and formal reasoning between students who followed case-based acid-base learning and students who followed scientific learning on the topic of acid-base.

2.4.2.2. Descriptive Analysis Statistics

Descriptive statistical analysis in this study to answer the problem formulation about the profile/level of student achievement on attitudes towards chemistry and formal reasoning of students. Descriptive analysis technique by interpreting the score into the ideal assessment category. The ideal assessment categories used according to (Widoyoko, 2013) can be seen in Table 3.

Table 3. Ideal Assessment Categories

No	Score range	Categories
1	$\bar{X} > \bar{Xi} + 1{,}8\ SBi$	Very good
2	$\bar{Xi} + 0{,}6\ SBi < \bar{X} \leq \bar{Xi} + 1{,}8\ SBi$	Good
3	$\bar{Xi} - 0{,}6\ SBi < \bar{X} \leq \bar{Xi} + 0{,}6\ SBi$	Quite
4	$\bar{Xi} - 1{,}8\ SBi < \bar{X} \leq \bar{Xi} - 0{,}6\ SBi$	Less
5	$\bar{X} \leq \bar{Xi} - 1{,}8\ SBi$	Very less

3. Result and Discussion

This research is quantitative research by conducting the learning process for four meetings each and ending with a posttest. The data taken in this study are quantitative data in the form of scores from case-based description questions and questionnaires on students' attitudes towards chemistry. This test aims to determine the simultaneous differences in students' chemical attitudes and significant formal reasoning between students who follow case-based acid-base learning and students who follow scientific learning on the topic of acid-base and determine the effectiveness of the contribution given.

3.1. Validity and Reliability Test

The formal reasoning test instrument is 16 description questions, each of which represents an aspect of formal reasoning. Analysis of students' formal reasoning questions uses the Rasch model with the help of the Quest program to determine the quality of the items and then determine the reliability value. The data seen is the suitability of the items with the Rasch Model. Test the suitability of each item of formal reasoning using Rasch Model items are said to be valid if they have infit MNSQ in the interval 0.77-1.33 (Boone et al., 2014). Based on QUEST analysis, the Infit MNSQ value for each question (item) of Formal Reasoning can be seen in Table 4.

Table 4. QUEST Analysis Result of Formal Reasoning Question Instrument

Statement Items	Infit MNSQ	Criteria	Statement Items	Infit MNSQ	Criteria
Item 1	0,96	Valid	Item 9	1,08	Valid
Item 2	0,91	Valid	Item 10	0,67	Invalid
Item 3	1,00	Valid	Item 11	1,07	Valid
Item 4	1,13	Valid	Item 12	1,04	Valid
Item 5	1,03	Valid	Item 13	0,92	Valid
Item 6	1,30	Valid	Item 14	0,76	Invalid
Item 7	1,35	Invalid	Item 15	0,57	Invalid
Item 8	1,20	Valid	Item 16	0,66	Invalid

The attitude assessment instrument towards chemistry is in the form of a self-assessment questionnaire. Testing the suitability of each statement in the questionnaire using the Rasch model which has acceptance limit criteria ≥ 0.77 to ≤1.30. The attitude towards chemistry questionnaire consists of 36 statement items that have been empirically tested. The data includes a dichotomous scale with five categories: a score of five represents strongly agree, four represents agree, three represents undecided, two represents disagree, and one represents strongly disagree. Furthermore, since this is dichotomous data, QUEST analysis using the Rasch model is applied. Based on the QUEST analysis, the Infit MNSQ for attitudes towards chemistry is presented in Table 5.

Based on Table 4, with 60 students used as objects of empirical validity, 11 questions were identified as fitting the Rasch model or deemed feasible, with a value of 0.98 within the acceptance limit of 0.77 ≤ Infit MNSQ ≤ 0.98. Table 5 indicates that all items fit the Rasch Model. The Infit MNSQ values for all 36 statement items in the attitude towards chemistry questionnaire fall within the acceptance limit of 0.77 ≤ Infit MNSQ ≤ 1.30. Furthermore, it can be concluded that all items of the attitude towards chemistry questionnaire statement are valid. The results of the output analysis of the attitude towards chemistry instrument show a reliability value of 0.9, so it can be concluded that the reliability of the attitude statement items towards chemistry has very good or very reliable criteria (Hair, et al., 2010). The complete results of this analysis can be seen in the appendix. The reliability test or Cronbach's alpha value obtained for the formal reasoning description test questions based on the question reliability test is 0.629, meaning that the reliability of the formal reasoning test questions has good or reliable criteria (Hair, et al., 2010).

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Table 5. Results of QUEST Analysis of Attitude Toward Chemistry Instrument

Statement Items	Infit MNSQ	Criteria	Statement Items	Infit MNSQ	Criteria
Item 1	0,97	Valid	Item 19	0,97	Valid
Item 2	1,00	Valid	Item 20	1,11	Valid
Item 3	0,99	Valid	Item 21	0,88	Valid
Item 4	0,99	Valid	Item 22	0,88	Valid
Item 5	1,02	Valid	Item 23	0,95	Valid
Item 6	1,03	Valid	Item 24	1,02	Valid
Item 7	1,10	Valid	Item 25	1,02	Valid
Item 8	1,01	Valid	Item 26	0,85	Valid
Item 9	0,98	Valid	Item 27	0,92	Valid
Item 10	0,92	Valid	Item 28	0,94	Valid
Item 11	0,99	Valid	Item 29	1,02	Valid
Item 12	0,98	Valid	Item 30	1,07	Valid
Item 13	1,05	Valid	Item 31	0,97	Valid
Item 14	0,93	Valid	Item 32	0,96	Valid
Item 15	1,04	Valid	Item 33	0,98	Valid
Item 16	1,09	Valid	Item 34	0,99	Valid
Item 17	1,14	Valid	Item 35	1,03	Valid
Item 18	0,97	Valid	Item 36	1,00	Valid

The difference between two variables against the action can be done by using the Hotelling T2 Test with the help of MANOVA analysis, so it must meet the nine prerequisite assumptions of MANOVA. Box's Test of Equality of Covariance Matrix (Box's M) The homogeneity assumption is met if the significance value is greater than 0.05. The test results can be seen in Table 6.

Table 6. The Results Homogeneity Test

Box's	F	Sig.
15,594	1,680	0,088

Based on Table 6, it can be seen that the significance value obtained is greater than 0.05, which means it can be concluded that the data in this study have met the assumption of a homogeneous covariance matrix. (9) No multi-collinearity was shown by looking at the Tolerance and VIF values, as shown in Table 7.

Table 7. The Result Multicollinearity Test

Model	Collinearity Statistics	
	Tolerance	VIF
Attitudes Toward Chemistry	0,983	1,017
Formal Reasoning	0,983	1,017

Based on Table 7, it can be seen that the Tolerace value for the variable attitude towards chemistry and Formal Reasoning is 0.983 or the Tolerace value> 0.1 which means that there is no multicollinearity, as well as for the VIF value obtained for the variable attitude towards chemistry and Formal Reasoning of 1.017 or the VIF value < 10. It can be concluded that this research data does not occur multicollinearity. The correlation between the dependent variables, attitudes towards chemistry and students' formal reasoning, is r = 0.261. Since this value falls within the range of 0.2–0.9, symptoms of multicollinearity are not detected.

3.2 Multivariate Test

The data were analyzed using multivariate MANOVA test with the help of SPSS software version 26 at 95% confidence level. This study uses Hotteling's Trace because the prerequisites of homogeneity of the variance-covariance matrix are met, there are two independent variables, the number of samples is met and the data is normally distributed. The results of the multivariate test (Hotteling's Trace) can be seen in Table 8.

Table 8. The Result of Multivariate Test

Effect		Value	F	Sig.
Strategi	*Hotelling's Trace*	.414	24.609^{b}	.000

The results in Table 8 obtained a significance value of 0.000 <0.05, which means it can be concluded that there are simultaneous differences in attitudes towards chemistry and significant formal reasoning between students who follow case-based acid-base learning and students who follow scientific learning on the topic of acid-base. In addition, the effective contribution of each case-based acid-base learning on attitude towards chemistry and case-based acid-base learning on Formal Reasoning can be seen in Table 9.

Table 9. Test of Between Subjects Effects on Attitude Toward Chemistry and Students' Formal Reasoning

Dependent Variable	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Attitudes Toward Chemistry	11824.559	3	3941.520	16.023	.000	.288
Formal Reasoning	1878.654	3	626.218	24.555	.000	.382

The results in Table 8 obtained a significance value of 0.000 <0.05, which means it can be concluded that there are simultaneous differences in attitudes towards chemistry and significant formal reasoning between students who follow case-based acid-base learning and students who follow scientific learning on the topic of acid-base (Slavin, 2018). Based on the Partial Eta Squared value, a value of 0.288 or 28.8% is obtained, meaning that the effective contribution of case-based acid-base learning has a high effect on attitudes towards chemistry on the topic of acid-base. Furthermore, the effective contribution of case-based acid-base learning on students' Formal Reasoning can be seen from the Partial Eta Squared value, which is obtained a value of 0.382 or 38.2%, meaning that the effective contribution of case-based acid-base learning also has a high effect on Formal Reasoning on the topic of acid-base. These results are in line with the research of Ozdilek (2015) which states case-based learning is able to make students acquire knowledge, skills and applications that are more content and context.

The emergence of many questions related to the case shows interest in learning chemistry, self-confidence in studying chemistry and knowing the usefulness of chemistry for a future career so that the process directly trains students' formal reasoning and attitudes towards chemistry. The difference in attitude results towards chemistry in the experimental class which is higher compared to the control class is influenced by the differences in learning provided in the two classes, so that students' beliefs and attitudes towards chemistry have the potential to increase or hinder learning as argued by Cam & Geban (2016) that cBL is effective and can improve attitudes towards chemistry. This is in line with research conducted by Minghong et al., (2019) concluding that case-based learning is active learning with a focus on students as the center of the learning environment, so that this learning is student-centered and oriented towards realistic environments and specific situations.

3.3. The Result Descriptive Analysis Statistics

The way to find out the profile of attitudes towards chemistry is to find the results of attitude scores towards chemistry in each group grouped in the ideal assessment category. The profile results can be seen in Table 10.

Table 10. Category Percentage of Attitude Toward Chemistry

Class	Categories				
	Very good	Good	Quite	Less	Very less
Experiment	8%%	52%	18%	22%	0%
Control	3%	23%	42%	26%	6%

Based on Table 10, both the experimental and control groups show a dominant positive attitude towards chemistry, with 52% of the experimental group and 23% of the control group rated as "good." Case-based learning contributes to this by encouraging students to be active and independent in problem-solving (Khan et al., 2015). Notably, 8 students in the experimental group were rated "very good" compared to only 3 in the control group. However, the control group had a higher percentage (26%) of students in the "sufficient" category, compared to 22% in the experimental group. Students' attitudes towards chemistry are reflected in their enthusiasm and interest in the subject (Nordin & Chin, 2010; Abulude, 2016). These findings align with Tarkin & Uzuntiryaki (2017), who found that case-based learning enhances students' understanding, attitudes, and intrinsic motivation in chemistry.

Furthermore, the data on formal reasoning ability obtained was analyzed by calculating the total percentage of formal reasoning ability on each indicator based on the ideal category. The results of the analysis of student achievement can be seen in Table 11.

Table 11. Percentage of Student Formal Reasoning Skills

Group	Reasoning Aspect	Categories
Experiment	Conservation	Good
	Proportional	Good
	Probability	Good
	Controlling Variables	Quite
	Correlation	Very good
	Combination	Very good
Control	Conservation	Less
	Proportional	Less
	Probability	Good
	Controlling Variables	Less
	Correlation	Quite
	Combination	Quite

Table 11 shows the Formal Reasoning skills of students in the experimental and control groups. In the experimental group, the level of conservation reasoning ability of 70% is included in the good reasoning category, then proportional reasoning ability of 61.6% and is included in the good category, probability reasoning of 78.3% is also included in the good category, but at the level of reasoning controlling variables is only 56% and is included in the sufficient category, correlation reasoning of 83.3% is included in the very good category, then combination reasoning of 85% is also included in the very good category. In the control class, it was found that the level of Formal Reasoning ability in the aspect of conservation reasoning was 37% including the category of insufficient reasoning, proportional reasoning ability of 32.5% included in the insufficient category, probability reasoning of 69.35% included in the good category, at the level of variable control reasoning only 30% and included in the insufficient category, correlation reasoning of 48.4% included in the sufficient category, then combination reasoning of 50% also included in the sufficient category.

Furthermore, from the data on formal reasoning skills, it can be concluded that in the experimental group the lowest indicator is the reasoning of controlling variables, only 56%, which means that students lack control over dependent and independent variables which influence hypothesis testing, which in this case is associated with cases of acid. bases such as acid rain reactions and the impacts they cause, then the acid-base indicators used in various acid-base solutions, but overall, in the experimental class the average indicators of formal reasoning are in the good and very good categories, the results of this research were confirmed by researchers Bansal & Goyal (2017) who stated that case-based learning can help students develop logical thinking, reasoning and interpretation. However, on the other hand, in the control group, the highest indicator of reasoning was only probability reasoning, meaning that students were sufficient in producing a certain result when repeated under the same circumstances in a larger context. Overall, students' formal reasoning in the control class tends to be poor compared to the experimental group. This is due to the low ability of students to conclude a problem based on existing evidence (Stainberg & Sebastian, 2013).

4. Conclusion

This study demonstrates that case-based learning is more effective than the scientific approach in improving students' attitudes towards chemistry and formal reasoning abilities, as evidenced by a significance value of 0.000 < 0.05. Case-based learning contributes an effective simultaneous impact of 36.6%, with 28.8% contributing to attitudes towards chemistry and 38.2% to formal reasoning abilities, both categorized as high. Furthermore, students who participated in case-based learning on acid-base topics exhibited better attitudes towards chemistry and stronger formal reasoning abilities across all aspects compared to those who engaged in scientific learning. Therefore, implementing a case-based approach is essential as an alternative method in chemistry education, aiming not only to enhance conceptual understanding but also to develop reasoning skills and foster a positive attitude toward the chemistry learning process.

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