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ARGUMENTATIVE STRATEGIES IN THE DEVELOPMENT OF CRITICAL THINKING SKILLS IN ENGINEERING STUDENTS

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Abstract

This study allowed to contribute and systematize the knowledge on the subject of the effects of the argumentative strategy in the development of critical thinking skills in engineering students, which will also allow the realization of other investigations. This research acquires significant relevance and topicality because we worked with modern theoretical constructs derived from the models of argumentation, critical thinking. The objective of this document was tofinalize the degree of relationship between argumentative strategies and critical thinking skills in Engineering students 2022. The results of this research constitute a reference for subsequent research at different levels on the effects of argumentative strategy on the development of critical thinking skills in engineering students from public universities in the rest of the country. Among the main findings, it was determined that between argumentative strategies and critical thinking skills there is a directly proportional relationship, of small to moderate effect in engineering students.

Keywords: Argumentative Strategies, Critical Thinking Skills, Higher Education.

1. Introduction

For the National Council of Science, Technology and Technological Innovation (Concytec), in Peru more than 13 thousand researchers are needed in engineering and basic sciences (La República, 07/03/2016). In addition, for the next few years, many of the jobs will be in fields and technologies that did not exist before, such as technology advocate, augmented reality developer or human technology integration specialist; among other specialties. Likewise, the World Economic Forum pointed out that there are 10 critical job skills that will be demanded in the future labor market. These include critical thinking, problem solving, creativity and team leadership in order to train more integral engineers,

more sensitive to human needs and prepared to face future challenges (Alcázar, 2018).

On the other hand, the World Declaration on Higher Education specifies as a mission of higher education institutions to train well-informed, highly motivated and critically capable students, who think not only about academic content but also about the daily problems of society, as well as propose solutions and assume social responsibilities (Unesco, 1998).

In that sense, new knowledge needs to be handled, but it must also be used for practical solutions to social needs in a context of social, political and economic crisis. This situation requires professionals with consistent arguments who possess a critical sense, who can act with criteria in any field of work, who must solve problems and who must make reasoned, thoughtful decisions. Therefore, the development of critical thinking plays a key role and is one of the most important goals of this century, both at the educational level and at the social level. Consequently, it becomes essential to activate the experience and practice of this type of thinking (Unesco, 2009).

University engineering students, at the beginning of their professional career studies, face various academic difficulties, which require reasoned, reflective, critical, creative and argued responses from them. Likewise, social demand requires training and having reflective, critical and argumentative engineers who face the problems generated by the increasingly complex and changing society. Faced with this demand, Tobón (2013) stated that the school must implement metacognitive strategies as necessary psychological tools so that students can observe, value, reflect, dialogue, criticize reality, assume positions that help transform themselves and transform their contexts as evidence of critical thinking achieved by students.

The way of evaluating the context of life demands students with critical thinking and solid arguments according to the changing needs in the framework of scientific and technological progress, intercultural globalization and the neoliberal economic model that is incorporated into educational processes as part of the modernization and transformation of higher education.

According to Romera (2019, p 2), students of the XXI century "need more to be than to know, starting from the basis that to be it is necessary to know. Knowing how to choose autonomously and responsibly, knowing how to think critically while being creative and disciplined". For our case, it would be knowing how to choose the appropriate argument.

According to Núñez, Ávila and Olivares (2017), the student of the XXI century needs to develop, in addition to professional skills, learning that allows him to perform better in his social and personal life.

Consequently, education must be extensive and must be projected beyond a transmission of knowledge. It should favor the construction of knowledge through reflection and critical thinking. For this, it is necessary to empower the student with the capacity for reflection, critical analysis of the situation, with strategies, such as argumentation, that allow them to convince with useful and necessary projects for society.

Professional needs and competencies demand the development of argumentation and critical thinking skills in engineering students. Engineers will evaluate reality with critical thinking; Then, they will propose alternative solutions.

The university in Peru finds itself with a weak academic process in the formation of critical capacity, a situation that becomes acute due to the scarce existence of highly qualified human resources that face this changing social reality (Luján, 2004). Faced with this situation, the research proposal is aimed at determining the effects of argumentative strategies on the development of critical thinking skills in a sample of engineering students from the National University of Engineering (UNI), during the 2022 academic year.

In the present research, the quantitative approach was assumed and is framed in the non-experimental perspective, in its correlational modality.

2. Objectives

2.1 General objective

To determine the degree of relationship between argumentative strategies and critical thinking skills in Engineering 2022 students.

2.2 Specific objectives

- Identify the predominant argumentative strategy in engineering students, 2022.

- Identify the predominant critical thinking skill in engineering students, 2022.

3. Hypotheses

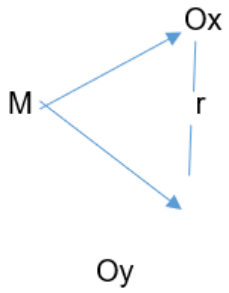
3.1 General hypothesis

There is a significant relationship between argumentative strategies and critical thinking skills in engineering students.

4. Methodology

4.1 Research design

A factual and non-experimental research was carried out in its correlational design with the aim of determining the significant relationship between argumentative strategies and critical thinking ability in engineering students in the 2022-1 cycle.



M = sample

Ox = argumentative strategies

r = relationship between argumentative strategies and critical thinking skills

Oy = critical thinking skills

4.2 Population and sample

The study population was made up of all engineering students, of medium and lower middle socioeconomic situation; of regular academic condition; whose ages range from 16 to 21, from the National University of Engineering. The sample consisted of 202 engineering students.

4.3 Instruments

1. Questionnaire of argumentative strategies

2. Critical Thinking Skills Questionnaire

Instrument validation:

The analysis of the psychometric properties of the instruments used in the study was performed using Confirmatory Factor Analysis (CFA) and the Internal Consistency method, for the exploration of evidence of validity and reliability, respectively.

For the AFC, it began by coding the observed responses in a dichotomous way (it managed to identify the evaluated construct = 1, it failed to identify the evaluated construct = 0). Subsequently, the items corresponding to each of the scales used in the present study were analyzed.

Regarding the EA scale (Table 1), mean scores of the items within the range [.04, .11] were observed, and measures in a way that denote a distribution of the data different from the normal one. Regarding discrimination indices, most items presented coefficients with adequate values (>.30) (r_itStreiner et al., 2015), while items 2, 4, 6 and 10 presented values lower than those established as adequate (r_it<.30).

Table 1. Item analysis of the Argumentative Strategies scale

Components	M	OF	S	K	r_{it}
Item 1	.04	.21	4.38	17.29	.35
Item 2	.07	.26	3.22	8.43	**.25**
Item 3	.08	.28	2.97	6.88	.43
Item 4	.09	.29	2.76	5.65	**.16**
Item 5	.10	.30	2.67	5.13	.33
Item 6	.08	.27	3.09	7.61	**.18**
Item 7	.16	.37	1.81	1.27	.34
Item 8	.11	.31	2.49	4.23	.37
Item 9	.08	.27	3.09	7.61	.36
Item 10	.11	.31	2.49	4.23	**.21**
Item 11	.06	.25	3.52	10.47	.36
Item 12	.11	.31	2.49	4.23	.31
Item 13	.09	.29	2.76	5.65	.31
Item 14	.11	.31	2.49	4.23	.43

Note: M: arithmetic mean, SD: standard or standard deviation, S: skewness, K: kurtosis, r_it: corrected item-test correlation.

Regarding the HPC scale (Table 2), mean values of the items within the range [.10, .37] were observed, and whose shape measurements indicate a clear divergence from the normal distribution. In addition, most items presented discrimination indices with values higher than .30 (>.30r_it) (Streiner et al., 2015); while items 1, 6, 26 and 28 presented values below adequate (r_it<.30).

Table 2. Item analysis of the Critical Thinking Skills scale

Components	*M*	*OF*	*S*	*K*	r_{it}
Item 1	.11	.31	2.49	4.23	**.21**
Item 2	.27	.44	1.04	-.92	.56
Item 3	.13	.34	2.14	2.58	.30
Item 4	.30	.46	.86	-1.27	.46
Item 5	.24	.43	1.22	-.50	.48
Item 6	.11	.32	2.41	3.84	**.16**
Item 7	.37	.48	.55	-1.71	.57
Item 8	.22	.41	1.36	-.16	.39
Item 9	.20	.40	1.50	.26	.56

Item 10	.19	.40	1.54	.38	.53
Item 11	.32	.47	.76	-1.43	.56
Item 12	.37	.48	.53	-1.73	.66
Item 13	.34	.48	.66	-1.57	.64
Item 14	.32	.47	.76	-1.43	.69
Item 15	.11	.32	2.41	3.84	.35
Item 16	.10	.31	2.58	4.66	.31
Item 17	.24	.43	1.22	-.50	.53
Item 18	.31	.46	.83	-1.32	.61
Item 19	.37	.48	.53	-1.73	.67
Item 20	.22	.41	1.36	-.16	.33
Item 21	.24	.43	1.19	-.58	.50
Item 22	.25	.44	1.13	-.72	.59
Item 23	.26	.44	1.07	-.85	.54
Item 24	.34	.48	.66	-1.57	.58
Item 25	.27	.45	1.02	-.97	.53
Item 26	.12	.33	2.27	3.16	**.21**
Item 27	.34	.47	.69	-1.54	.52
Item 28	.21	.41	1.39	-.06	**.26**
Item 29	.19	.39	1.58	.51	.47
Item 30	.29	.46	.91	-1.18	.54
Item 31	.31	.46	.81	-1.36	.53
Item 32	.33	.47	.71	-1.50	.53

Note: M: arithmetic mean, SD: standard or standard deviation, S: skewness, K: kurtosis, r_it: corrected item-test correlation.

Once the descriptive analysis of the scores of the items of each scale was carried out, we proceeded to explore evidence of validity based on the internal structure of the tests. For this purpose, an AFC was made to the theoretical structures proposed for the instruments. The estimation method used was a robust variant of weighted least squares (WLSMV), given the ordinal nature of the items and having fewer than 5 answer options. Adjustment was assessed using the following adjustment indices (approximate fit value shown in parentheses: x^2/gl (< 3.0), CFI (> .95), TLI (> .96), RMSEA (< .06), and WRMR (< 1.0) (Abad et al, 2011; DiStefano et al, 2018; Hu & Bentler, 1999).

Regarding the EA scale (Table 3), a lack of adjustment of the empirical data to the theoretical models of the dimensions of the scale was found: Ratio (/gl=1.74, CFI=.84, TLI=.79, RMSEA=.06, WRMR=x^21.0) and Counter-argumentation (/gl=2.16, CFI=.89, TLI=.67, RMSEA=.08, WRMR=.x^248). However, an approximate adjustment of the empirical data was obtained to a model of 2 related factors (x^2/gl=1.35, CFI=.88, TLI=.86, RMSEA=.04, WRMR=.95), but the covariance relationship between the constituent factors of this model (Reason and Counter-

argumentation) was .90, which suggests that both factors cannot be differentiated into independent entities. Consequently, a unifactorial model was evaluated, which presented adjustment indices close to adequate, but without being conclusive (x^2/gl=1.34, CFI=.89, TLI=.86, RMSEA=.04, WRMR=.96); also, a unifactorial model was evaluated from which the 4 items (2, 4, 6 and 10) that did not achieve discrimination indices higher than .30 were removed; however, this did not represent changes in the fit of the data to the model (x^2/gl=1.69, CFI=.88, TLI=.85, RMSEA=.06, WRMR=.99). We sought to analyze bifactor and second-order factorial structures; However, this led to complex solutions that could not be explored due to the requirements they presented.

Table 3. Confirmatory factor analysis of the scale of Argumentative Strategies

Scales	N° Items	x^2(gl)	p	x^2/gl	CFI	TLI	RMSEA	WRMR
Reason	10	60.87 (35)	<.001	1.74	.84	.79	.06	1.00
Counter-argumentation	4	4.31 (2)	.12	2.16	.89	.67	.08	.48
Model 2 independent factors	14	200.18 (77)	<.001	2.60	.46	.37	.09	1.60
Model 2 related factors	14	102.78 (76)	.02	1.35	.88	.86	.04	.95
Model 1 general factor	14	103.06 (77)	.03	1.34	.89	.87	.04	.96
	10	59.26 (35)	.01	1.69	.88	.85	.06	.99

Note: Chi-squared distribution statistic, gl: degrees of freedom, x^2p: critical value of the null hypothesis rejection region at 95% confidence, RMSEA: root mean square error of approximation, CFI: c omparative fit index (comparative fit index), WRMR: weighted root mean square residual, TLI: Tucker–Lewis index.

5. Results

The correlation analysis determined that a directly proportional relationship is present between AEs and HPCs, with a small to moderate effect (ρ=.29, 95% CI [.15, .41]) and statistically significant (p<.001), in addition to a common variance ratio of 8% (=.08). Additionally, the subdimensions Ratio (ρ=.29, 95% CI [.16, .41]) and Counterargument (ρ=.15, 95% CI [.00, .28]) of AEs presented statistically significant (r^2p<001) relationships with HPC, and whose effect sizes were small (r<.30) (Aron et al., 2013).

Table 4. Correlation Argumentative Strategies – Critical Thinking Skills

Scales	1	2	3	4
1. Argumentative strategies (EA)	-			
2. EA: Reason	.94 [.92, .95]	-		

3. EA: Contraargumentación	.69 [.60, .75]	.44 [.32, .55]	-	
4. Critical thinking skills	**.29** [.15, .41]	**.29** [.16, .42]	**.15** [.00, .28]	-

Note: The matrix is composed of Spearman correlation indices [ρ]. All indices presented were statistically significant (p<.05).

In addition, we sought to know whether AEs had an effect on HPC scores. For this purpose, a non-parametric version of the T test was used for independent samples (Mann Whitney U) (Montanero and Minuesa, 2018). The results (Table 5) revealed the presence of statistically insignificant differences (p>.05), so we opted for the preservation of the null statistical hypothesis. Consequently, it was established that the differences between the groups were minimal (Reason: M=9.76, Counter-argumentation: M=9.90). In addition, the effect size used for this test revealed a null association (r_b=.02) between the variables EA and HPC.

Table 5. HPC – EA Benchmarking

Groups	*M (DE)*	Inferential analysis		r_b
		In the	*p*	
Argumentative strategies				
Reason	9.76 (6.92)	1251	.893	.02
Contraargumentación	9.90 (8.20)			

Note: M (SD): mean (standard deviation), U: Mann-Whitney range statistic, : biserial range correlation coefficient (effect size of the U statisticr_b), p: critical value of the null hypothesis rejection region at 95% confidence.

We also sought to know whether the dimensions that make up AEs have an effect on HPC (Table 6). For this, the non-parametric version of the one-way analysis of variance (Kruskal – Wallis) was used (Montanero and Minuesa, 2018). The analysis determined that the HPC scores did not present statistically significant differences depending on the AEs of Ratio (p>.05); however, a medium-sized effect (η^2=.06) was determined, indicating that Ratio AEs explain 6% of the variation in HPC scores. On the contrary, statistically significant differences (p<.05) were found in the HPC scores depending on the Counter-argumentation AEs used by the students. A post-hoc analysis determined that the mean scores of Concession (M=13.04, SD=7.32) were higher than those of Rebuttal (M=6.50, SD=6.74). Additionally, a large effect (η^2=.14) was observed, which indicated that Counter-argument AEs explained 14% of the variation in HPC scores.

Table 6. HPC multigroup comparative analysis – EA dimensions

Groups	*M (DE)*	Inferential analysis		η^2	Post-hoc analysis
		H	*p*		
EA: Reason					
Authority	12.45 (9.14)	5.361	.373	.06	-
Example	9.13 (8.40)				
By analogy	7.93 (6.57)				
About the causes	8.13 (6.45)				
Rhetorical question	6.44 (7.89)				
Several	11.06 (7.05)				
EA: Counter-argumentation					
Concession	13.04 (7.32)	9.298	<.05	.14	Concession > Rebuttal
Refutation	6.50 (6.74)				
Both	9.50 (11.01)				

Note: M (SD): mean (standard deviation), H: Kruskal-Wallis statistic, p: critical value of the rejection region of the null hypothesis at 95% confidence, size of the eta square effect. η^2

The evidence collected (Table 7) showed that 51.5 % presented a predominance by one of the 2 groups of AE: Reason (59.6%) and Counter-argumentation (39.4 %), and only 1 case (1 %) was presented where both were predominant; however, the remaining 48.5% did not present any predominance over these.

Regarding the AE of Reason, it was observed that in 38.3% of the participants the use of more than one AE corresponding to this dimension predominates, with the EA by Analogy being the most predominant individually (14.9%), and the EA About the causes as the least predominant (8.5%).

On the other hand, with regard to the AEs of Counter-argumentation, it was found that the Concession was the predominant AE (44.4%) in the evaluated group, followed by the Rebuttal (40.7%), and the use of both AEs as the one with the lowest predominance in the sample (14.8%).

Table 7. Predominant argumentative strategies in the sample

Argumentation strategies	n	%
Reason strategy	62	59.6
Authority	11	11.7
Example	16	17
By analogy	14	14.9

About the causes	8	8.5
Rhetorical question	9	9.6
More than one EA of Reason predominates	36	38.3
Counter-argumentation strategy	41	39.4
Concession	24	44.4
Refutation	22	40.7
Both EA of counter-argumentation predominate	8	14.8

Note: n: number of cases observed, %: relative frequency percentage.

Regarding HPC (Table 13), it was found that 85.2 % (n=172) of the participants presented some type of predominance over these skills, while 14.8 % did not present mastery over them. Of the first referrals, 27.9 % had more than one predominant HPC, while about 72.1 % had only one predominant HPC. Regarding the individual predominance of HPC, the ability to synthesize was the most predominant in the sample (16.9 %), while Interpretation was the least predominant (2.9 %).

Table 8. Predominant critical thinking skills in the sample

Critical thinking skills	n	%
Analyze	12	7.0
Compare	14	8.1
Interpret	5	2.9
Inferir o razonar	21	12.2
Synthesize	29	16.9
Argue	19	11.0
Evaluate	24	14.0
More than one predominant	48	27.9
Total	172	85.2

Note: n: number of cases observed, %: relative frequency percentage.

6. Discussion

In the engineering career, they must submit design proposals and must attend public and private calls where their justification must be based on demonstrating with evidence and arguments that a certain project is feasible or should be carried out for the benefit of the community. The reasoning to justify proposals through argumentation occurs through more complex thought processes than those that require explanation, description or narration, so they must be included in formal teaching (Flores, Franco, Raygoza and Vargas, 2018).

The result of the study indicates that between argumentative strategy and critical thinking skills there is a directly proportional relationship, of small to moderate effect. This result, due to the correlation between the variables, is little studied. However, related studies show results slightly coinciding with the subdimensions.

It is striking that, in terms of argumentative strategies, the argumentative subdimension of example predominates and the subdimension of causes is the least predominant in engineering students. This indicates that engineering students have a very specific thought because to understand a theoretical content they require a case, an exemplification, a real reference that is easy to understand and that corresponds to what you want to transmit. However, having little incidence in the aspect of causes puts at risk their training as scientists since engineering and science are two sides of the same coin and the question of science is mostly a question of causes. It would be important to suggest the teaching of the history of science course so that the student understands the importance of asking about the causes and how it has characterized the thinking of great scientists.

It was found that engineering students are concesive and little refutative to the arguments of others. That is, in the sample studied it was found that they simply accept the opinions of others and do not usually contradict the arguments of others. This indicates that, in reality, they do not know how to confront a contrary position because they lack the ability to criticize. This type of skill is usually developed in philosophically oriented courses such as ethics, political philosophy, or epistemology. Likewise, it would be good if the official debate group of the UNI "UNI Debate Society" could carry out some talks with teachers or students to be able to show and exemplify how the process of refutation of the thesis of an adversary occurs.

The critical thinking ability to synthesize was the most predominant in the sample. On the other hand, interpretation was the least predominant in the sample of engineering students. This indicates that students and engineering know how to draw conclusions which is a good sign that they have some notion of what logic is at an acceptable level. Also, they are able to summarize relevant information according to their purposes. However, the fact that they are not given to interpretation reveals that they are not very devoted to reading. This is understandable because on average in engineering courses the student only reads books filled with formulas, data, theorems and technical indications. Therefore, engineering students need to be closer to the humanities. Through contact with the humanities they will be obliged to read and, in addition, to understand and interpret what they read so that they understand that the meaning of a text depends on the level of understanding of the reader and, in addition, on other circumstantial circumstances.

Regarding the argumentative strategy, the study of Bova (2022) has been found, with whom it is possible to coincide in the subdimensions of study. Study the argumentative strategies most used by parents to resolve argumentative conversations with their offspring at the time of the family reunion in their favor. These are arguments based on the notions of quality and quantity of food-related discussions. Parents also use other types of arguments, such as appeal to coherence, arguments of authority and arguments of analogy, in discussion related to the teaching of correct behavior in social situations outside the family context.

On the other hand, the studies of Jiménez, G and Vega, L (2018), at the Autonomous University of Mexico, on the argumentative strategies used by preschool children in natural situations of interaction in the classroom, showed that in the conversations they had with their teachers and among peers they generated 10 argumentative strategies: authority referent, description, comparison, analogy, generalization, narration, anticipation, causality, opposition and alternative proposal.

For Serrano, González, Olivares (2015), the Strategies and modalities of oral argumentation in the assemblies of Early Childhood Education, children base their arguments based on empirical data. They use their experiences, both school and family, as the first source of information to support their interventions.

The work of Huamán (2016), at the University of César Vallejo in Tarapoto, should also be considered. From the study, it can be highlighted that the use of argumentation as a learning strategy strengthens the development of oral competence, since it allows the student to build speeches with greater reasoning making use of arguments with full knowledge and considering in what communicative context they can use them to fulfill their purpose. This study reinforces our original proposal that aims at EA for the promotion of knowledge of the future engineer.

It also highlights the work of Costabalo, Valladares and Espinoza (2022) who confirm that argumentative strategies influence the use of critical thinking, although they found weaknesses in reasoning with logical sense. In addition, they emphasize that it is necessary to develop competencies to promote analytical, inferential and interpretative attitudes, emphasizing individual self-regulation.

The work of Muñoz (2019) serves as a guide, who concludes that the argumentative processes of the students were weak in the light of the quality model of the arguments of Sampson and Clark (2009), rather the superficial arguments prevailed characterized by expressing only their own beliefs not based on written or oral sources, which influenced the absence of the use of any argumentative strategy to justify statements, So they stayed in the mere opinion.

Regarding the variable of critical thinking skills, Parra (2018) argues that educators should promote argumentation and reflective criticality in the educational space. For Alquichirre and Arrieta (2018), there is a relationship between average academic performance and average critical thinking skills.

The studies of Ossa, Palma, Lagos and Días (2018) confirm the importance of using the development of critical thinking in the university as it has positive effects on the level of achievement of students.

Likewise, Albisuaa, Ruizb, Fernández, Arranz, and Campo (2018) conclude that teachers link critical thinking with processes of analysis and reasoning, some to questioning, evaluation and decision-making and very few understand it as action and commitment. They stress that it is very important for university education.

For Mota de Cabrera (2010) the use of argumentative diagrams improves the capacities of analysis, understanding, evaluation and argumentation in students. However, for Sierra, Carpintero and Pérez (2010) the lack of use of critical thinking in schoolchildren, either in the school environment or in daily life prevents independent development. The authors referred to agree that argumentative processes involve analysis, synthesis, elaboration of argumentative judgments, logical and critical thinking. The training of individuals in such skills favors critical reading, reflection and research, in such a way that it is promoted as one of the purposes of education.

7. Conclusions

1. It was determined that between argumentative strategies and critical thinking skills there is a directly proportional relationship, of small to moderate effect in engineering students.

2. Regarding argumentative strategies, the argumentative subdimension of example predominates and the subdimension of causes is the least predominant in engineering students.

It was also found that engineering students are concessional and little refutative to the arguments of the issuers. That is, in the sample studied it was found that they accept the opinions and are little to contradict the arguments of the issuers.

3. Regarding critical thinking skills, the ability to synthesize was found to be the most predominant in the sample, while interpretation was the least predominant in the sample of engineering students.

8. Recommendations

1. Given the importance of training students with high argumentative capacity so that they can convince their occasional interlocutors with their projects, as professionals, it is necessary to reinforce the argumentative strategy in the different subjects of study. In some European universities, argumentation is an event, an inter-university competition.

2. Training in the use of critical thinking is a necessity of the time. It is part of the soft skill that every professional must have; Therefore, the need for the University to train in this competence is transcendental. It is recommended to consider all the subjects of the curriculum as a transversal axis.

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