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Measurement of the effectiveness of an educational program inspired by indigenous knowledge for forest management, applied to Forest Engineering students at the National University of Central Peru, using the neutrosophic 2-tuple linguistic method

Melina Lisbet[1], Rubén Gelacio Caballero Salas[2], Milciades Aníbal Baltazar Ruiz[3], Carlos Eduardo Caballero Salas[4], Guillermo Ayllon Pinchi[5], Rolando Carlos Canteño Gavino[6], Keneth Reategui del Aguila[7], Wilmer Ortega Chávez[8]

[1] Melina Lisbet, Caballero Miranda, Universidad Nacional del Centro del Perú, Perú. Orcid. https://orcid.org/0000-0002-7155-3564 Email: mcaballero@uncp.edu.pe

[2] Rubén Gelacio Caballero Salas, Universidad Nacional del Centro del Perú, Perù. Orcid: https://orcid.org/0000-0003-1412-2933 Email: rcaballero@uncp.edu.pe

[3] Milciades Aníbal Baltazar Ruiz, Universidad Nacional del Centro del Perú, Perù. Orcid: https://orcid.org/0000-0001-8829-1153 Email: mbaltazar@uncp.edu.pe

[4] Carlos Eduardo Caballero Salas, Universidad Nacional del Centro del Perú, Perù. Orcid: https://orcid.org/0000-0002-7546-6572 Email: cecaballero@uncp.edu.pe

[5] Guillermo Ayllon Pinchi, Universidad Nacional de Ucayali, Pucallpa Perù, https://orcid.org/0009-0000-9593-7055 Email: gui_ayllon@hotmail.com

6 Rolando Carlos Canteño Gavino, Universidad Nacional de Ucayali, Pucallpa Perù, https://orcid.org/0000-0003-2238-6269 , rolando_canteno@unu.edu.pe

[7] Keneth Reategui del Aguila, Universidad Nacional Intercultural de la Amazonìa, Ucallali, Pucallpa Perù, https://orcid.org/0000-0002-0201-2596 Email: kreateguid@unia.edu.pe

[8] Wilmer Ortega Chávez, Universidad Nacional Intercultural de la Amazonìa, Ucallali, Pucallpa Perù, https://orcid.org/0000-0002-5888-2902, Email: wortegac@unia.edu.pe

Abstract. The "guide to Asháninka knowledge for forest management" is a document prepared by academics and scientists from the National University of Central Peru (NUCP) in the Faculty of Forestry Engineering, which includes the knowledge of this indigenous people about forest nature. Despite being ancestral knowledge, we believe that it can serve as a complement to the scientific study of the subject since it is based on knowledge accumulated over centuries of experience. The main purpose of this article is to determine the influence of the "Ashaninka knowledge guide for forest management" on the learning level of NUCP Forest Engineering students. To accomplish these objectives, Asháninka knowledge was compiled, and the learning guide was designed and applied to the students. 36 students from the faculty were taken as part of the study, to whom two tests were administered, one before studying the guide and another after. The tests consisted of questionnaires on knowledge about the guide and the forests. A neutrosophic linguistic scale was used for respondents to answer both tests. The advantage of this methodology is that experts could evaluate more easily with the help of natural language, in addition to the fact that the incorporation of neutrosophy helps to take into account indeterminacy and therefore there is more accuracy. Specifically, the Neutrosophic 2-tuple linguistic method was used. The results were converted to crisp numbers and the evaluations of the two tests were compared with the help of the Wilcoxon test.

Keywords: Knowledge of indigenous peoples, Asháninka people, Forest Engineering, neutrosophic 2-tuples linguistic method, Wilcoxon range test.

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1 Introduction

The United Nations Conference on Environment and Development (UNCED, 1992), held in Brazil, was a defining moment for the promotion of the rights of indigenous peoples about the environment.

A series of legal standards were adopted, such as the Rio Declaration, the Convention on Biological Diversity (CBD), and Agenda 21, and international legal standards were established to protect the traditional knowledge and practices of indigenous peoples in matters of management and environmental Conservation.

Indigenous peoples are the agents of the greatest diversity in the world, they host not only biological diversity but also cultural, linguistic, and landscape diversity, etc. Their modes of existence vary from one place to another, of the 6,000 cultures that exist in the world (approximate figure), 4,000 to 5,000 cultures are indigenous. 6,000 languages in the world are spoken by indigenous peoples, most importantly, most of the Earth's biological diversity is inhabited by these peoples. The countries with the greatest indigenous presence are Australia, Brazil, China, Colombia, Ecuador, the United States of America, the Philippines, India, Indonesia, Madagascar, and Malaysia.

This research is intended to incorporate ancestral knowledge in the training and professional practice of the Forest Engineer, in a learning guide, with the research problem consisting of determining how the "Asháninkas Knowledge (AK) Guide" influences the management of forests in the learning level of Forest Engineering students at the National University of Central Peru (NUCP).

AK and scientists do not exclude each other but rather complement each other. The use of Asháninka knowledge in forest management contributes to improving the implementation of a project, learning module, workshop, or guide by providing valuable information about the local context, both at the landscape and ecosystem levels. Furthermore, it may be able to increase long-term sustainability, while strengthening the self-esteem of communities, helping them participate in local and national development.

The incorporation of ancestral knowledge in the curricular plans of professional and technical careers in our country would have positive impacts, such as changes in attitude, thoughts, and environmental awareness. At the National University of Central Peru, two faculties have professional courses in Forest Engineering, but neither of them has incorporated a module, guide, or course related to ancestral knowledge. For the reasons mentioned, the general motivation of the research is: to determine the influence of the "AK guide for forest management" on the learning level of NUCP Forest Engineering students, for which, it was taken into account the following specific objectives: Compile information from AK focused on forest management; design the "AK guide to forest management"; and apply the guide to NUCP Forest Engineering students.

To quantitatively measure the result of this learning methodology there are some challenges, first of all, the student's learning must be measured, which is why we proposed to carry out a test where the students show the learning acquired, first before studying the guide and a test for later. The second challenge is to measure results that are subjective and contain indeterminacy, for this, we use the neutrosophic 2-tuple linguistic model [1-3]. Finally, to process the data we measure the general situation with the support of the non-parametric Wilcoxon sign test [4, 5].

The neutrosophic method generalizes the well-known 2-tuple linguistic method from the fuzzy outline to the neutrosophic framework [6-8]. The advantages of this model are its simplicity, effectiveness, and veracity, since the respondent expresses his or her opinion on a linguistic measurement scale, which is understandable to everyone. This method is an example of Computing with Words (CWW) introduced by L. Zadeh, where calculation with words is preferred over calculation with numbers, which corresponds to the usual way that humans evaluate [9-11]. Additionally, the neutrosophic framework helps to incorporate indeterminacy as part of the evaluation.

The Wilcoxon signed-rank test is a nonparametric test to compare the mean rank of two related samples and determine if there are differences between them [4, 5]. It is used as an alternative to the Student t-test when the normality of these samples cannot be assumed. In the article, we convert the result of the 2-tuple linguistic methods into numerical crisp values and we apply the Wilcoxon sign test on them.

This paper is divided into a Materials and Methods section, where the basic notions of the neutrosophic 2-tuple linguistic method are explained. Section 3 consists of the presentation of the results obtained in this study. The final section contains the Conclusions. An Annex is also included with the applied tests for the students and the data collected.

2 Materials and Methods

This section contains the basic concepts of the neutrosophic 2-tuple linguistic model and notions of the Wilcoxon rank test.

Definition 1 ([6]). Let $S = \{s_0, s_1, \dots, s_g\}$ be a set of linguistic terms and $\beta \epsilon [0, g]$ is a value that represents the result of a symbolic operation, then the *linguistic 2-tuple* that expresses the information equivalent to β, is obtained using the following function:

$\Delta: [0, g] \rightarrow S \times [-0.5, 0.5)$
$\Delta(\beta) = (s_i, \alpha)$ (1)

Where s_i is such that $i = \text{round}(\beta)$ and $\alpha = \beta - i$, $\alpha \in [-0.5, 0.5)$ and "round" is the usual rounding operator, s_i is the index label closest to β and α is the value of the *symbolic translation.*

It should be noted that $\Delta^{-1}: \langle S \rangle \rightarrow [0, g]$ is defined as $\Delta^{-1}(s_i, \alpha) = i + \alpha$. Thus, a linguistic 2-tuple ⟨S⟩ is identified with its numerical value in $[0, g]$.

Suppose that $S = \{s_0, \dots, s_g\}$ is a *2-Tuple Linguistic Set* (2TLS) with odd cardinality g+1. It is defined for $(s_T, a), (s_I, b), (s_F, c) \in L$ and a, b, c ∈[0, g], where $(s_T, a), (s_I, b), (s_F, c) \in L$ independently express the degree of truthfulness, indeterminacy, and falsehood by 2TLS. *2-Tuple Linguistic Neutrosophic Number* (2TLNN) is defined as follows ([1-3, 12-16]):

$l_j = \left\{(s_{T_j}, a), (s_{I_j}, b), (s_{F_j}, c)\right\}$ (2)

Where $0 \le \Delta^{-1}(s_{T_j}, a) \le g$, $0 \le \Delta^{-1}(s_{I_j}, b) \le g$, $0 \le \Delta^{-1}(s_{F_j}, c) \le g$, and $0 \le \Delta^{-1}\left(s_{T_j}, a\right) + \Delta^{-1}\left(s_{I_j}, b\right) + \Delta^{-1}(s_{F_j}, c) \le 3g$.

The *scoring* and *accuracy functions* allow us to rank 2TLNN.

Let $l_1 = \left\{(s_{T_1}, a), (s_{I_1}, b), (s_{F_1}, c)\right\}$ be a 2TLNN in L, the scoring and accuracy functions in l_1 are defined as follows, respectively:

$$\mathcal{S}(l_1) = \Delta\left\{\frac{2g + \Delta^{-1}(s_{T_1}, a) - \Delta^{-1}(s_{I_1}, b) - \Delta^{-1}(s_{F_1}, c)}{3}\right\},\ \Delta^{-1}(\mathcal{S}(l_1)) \in [0, g] \quad (3)$$

$$H(l_1) = \Delta\left\{\frac{g + \Delta^{-1}(s_{T_1}, a) - \Delta^{-1}(s_{F_1}, c)}{2}\right\},\ \Delta^{-1}(H(l_1)) \in [0, g] \quad (4)$$

Formula of Wilcoxon test is Equation 5 ([4, 5]):

$$W = \sum_{i=1}^{N_r}\left[sgn(x_{2,i} - x_{1,i}) \cdot R_i\right] \quad (5)$$

Where:
W: is the test statistic,
N_r: is the size of the sample, excluding values $x_1 = x_2$,
sgn: is the sign function,
$x_{1,i}, x_{2,i}$: are the pairs of related ranges of two different distributions,
R_i: range i.

This test is used to determine if there are differences between both populations. The objective is to know if there is a significant improvement in the student's knowledge of forest engineering science when they study the Asháninka knowledge guide. The null hypothesis of the test is that the mean difference between both populations is 0, while the alternative hypothesis is that there is a significant difference between both and therefore both populations are different.

3 Results of the study

Next, we describe the method followed to carry out the present study. Firstly, we define the linguistic scale on which we will base the tests. This is the one shown below:

1. An initial linguistic scale is defined on which the evaluations will be based, this is: $S = \{"Deficient", "Regular", "Good", "Very\ Good", "Excellent"\}$ or equivalently $S = \{s_0, s_1, s_2, s_3, s_4\}$, this grade is the one that will be given for each of the aspects to be evaluated in the test to each of the evaluated students. That is, each of the 36 students e_i $i \in \{1, 2, \dots, 36\}$ answers a questionnaire of 13 questions. The evaluator gives a grade for each student according to a triple of linguistic values on the scale S, as shown below:

$\rho_{ij} = \left(s_{\rho ijT}, s_{\rho ijI}, s_{\rho ijF}\right)$ for the pre-test and $\theta_{ij} = \left(s_{\theta ijT}, s_{\theta ijI}, s_{\theta ijF}\right)$ for the post-test, where the elements of the triples belong to the scale S such that $s_{\rho ijT}$ and $s_{\theta ijT}$ are the linguistic values of truthfulness, $s_{\rho ijI}$ and $s_{\theta ijI}$ are the linguistic values of indeterminacy, and $s_{\rho ijF}$ and $s_{\theta ijF}$ are the linguistic values of falsity.

2. Each student e_i has a final grade $\rho_i = (s_{\rho iT}, s_{\rho iI}, s_{\rho iF})$ and $\theta_i = (s_{\theta iT}, s_{\theta iI}, s_{\theta iF})$, obtained as the arithmetic mean of their results according to the assessment given by the experts regarding certain aspects of the answers. Details of the surveys appear in the Annex.

   That is, these triples are obtained from values $\beta_i^\rho = (\beta_{iT}^\rho, \beta_{iI}^\rho, \beta_{iF}^\rho)$, $\beta_i^\theta = (\beta_{iT}^\theta, \beta_{iI}^\theta, \beta_{iF}^\theta)$ where:

   $\beta_{iT}^\rho = \frac{\sum_{j=1}^{9} k_{ijT}^\rho}{9}$, $\beta_{iT}^b = \frac{\sum_{j=1}^{9} k_{ijT}^\theta}{9}$;

   $\beta_{iI}^\rho = \frac{\sum_{j=1}^{9} k_{ijI}^\rho}{9}$, $\beta_{iI}^b = \frac{\sum_{j=1}^{9} k_{ijI}^\theta}{9}$;

   $\beta_{iF}^\rho = \frac{\sum_{j=1}^{9} k_{ijF}^\rho}{9}$, $\beta_{iF}^b = \frac{\sum_{j=1}^{9} k_{ijF}^\theta}{9}$;

   Where:

   k_{ijT}^ρ, $k_{ijT}^\theta \in \{0, 1, 2, 3, 4\}$ are the indices of truthfulness evaluations for each answer given in the survey by the student e_i, in the pre-test and post-test, respectively.

   k_{ijI}^ρ, $k_{ijI}^\theta \in \{0, 1, 2, 3, 4\}$ are the indices of the indeterminacy evaluations for each answer given in the survey by the student e_i, in the pre-test and post-test, respectively.

   k_{ijF}^ρ, $k_{ijF}^\theta \in \{0, 1, 2, 3, 4\}$ are the indices of falsehood evaluations for each answer given in the survey by the student e_i, in the pre-test and post-test, respectively.

3. For each $\beta_i^\rho = (\beta_{iT}^\rho, \beta_{iI}^\rho, \beta_{iF}^\rho)$y $\beta_i^\theta = (\beta_{iT}^\theta, \beta_{iI}^\theta, \beta_{iF}^\theta)$ we get a triple symbolic translations denoted by $\alpha_i^\rho = (\alpha_{iT}^\rho, \alpha_{iI}^\rho, \alpha_{iF}^\rho)$ and $\alpha_i^\theta = (\alpha_{iT}^\theta, \alpha_{iI}^\theta, \alpha_{iF}^\theta)$. This is how we obtain the pairs $l_i^\rho = \left((s_{\rho iT}, \alpha_{iT}^\rho), (s_{\rho iI}, \alpha_{iI}^\rho), (s_{\rho iF}, \alpha_{iF}^\rho)\right)$ and $l_i^\theta = \left((s_{\theta iT}, \alpha_{iT}^\theta), (s_{\theta iI}, \alpha_{iI}^\theta), (s_{\theta iF}, \alpha_{iF}^\theta)\right)$.

4. $x_i = \Delta^{-1}(\mathcal{S}(l_i^\rho))$ and $y_i = \Delta^{-1}\left(\mathcal{S}(l_i^\theta)\right)$ are obtained.

5. The Wilcoxon test is applied to determine if both populations are equal. If the p-value satisfies $p \leq 0.05$ then the null hypothesis is rejected, which means that there is a significant improvement in the students' mastery of the knowledge that appears in the guide.
   Otherwise, it is interpreted that there is no significant improvement after studying the guide.

Next, we present the results obtained from the calculations.

Once the survey questions were answered by each of the students, an expert on the subject who is a professor at the Faculty of Forestry Engineering in charge of these topics was asked to evaluate the students' results. The nine criteria to measure the results of the survey are shown in Table 1.

Criterion to evaluate	Explanation	Deficient	Regular	Good	Very good	Excellent
1. CLARITY	Respond in an appropriate language		To be filled out by the interviewer			
2. OBJECTIVITY	Responses are expressed in observable behaviors		To be filled out by the interviewer			
3. CURRENT NEWS	The answers are appropriate to the advancement of science and technology		To be filled out by the interviewer			
4. ORGANIZATION	There is a logical organization in the answers		To be filled out by the interviewer			
5. SUFFICIENCY	Understand aspects of quantity and quality		To be filled out by the interviewer			
6. INTENTIONALITY	Suitable for im-		To be filled out by the interviewer			

	provement and attitudes towards environmental conservation.	
7. CONSISTENCY	Based on theoretical–scientific aspects of Forest Sciences	To be filled out by the interviewer
8. COHERENCE	There is consistency between the answers to each of the questions asked	To be filled out by the interviewer
9. METHODOLOGY	The strategy responds to the purpose of the diagnosis	To be filled out by the interviewer

Table 1: Criteria to measure in student's evaluation.

For greater ease for the evaluator regarding the use of the neutrosophic 2-tuples, a triple was suggested for each type of evaluation, although he had the possibility of changing each of the values if he considered it necessary.

Evaluation/Triple	(s_T, a)	(s_I, b)	(s_F, c)
Deficient	$(s_0, 0)$	$(s_0, 0)$	$(s_4, 0)$
Regular	$(s_2, 0)$	$(s_2, 0)$	$(s_2, 0)$
Good	$(s_3, 0)$	$(s_1, 0)$	$(s_1, 0)$
Very good	$(s_3, 0)$	$(s_0, 0)$	$(s_0, 0)$
Excellent	$(s_4, 0)$	$(s_0, 0)$	$(s_0, 0)$

Table 2: Values suggested to the evaluator as a linguistic triple.

Figures 1 and 2 show the absolute frequency of the responses, before and after the students' training, respectively.

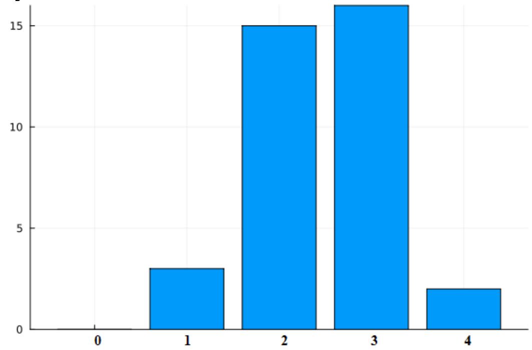

Figure 1: Bar graph with the results of the final evaluative indices in the pre-test. The abscissa shows the indices and the ordinate shows the absolute frequency.

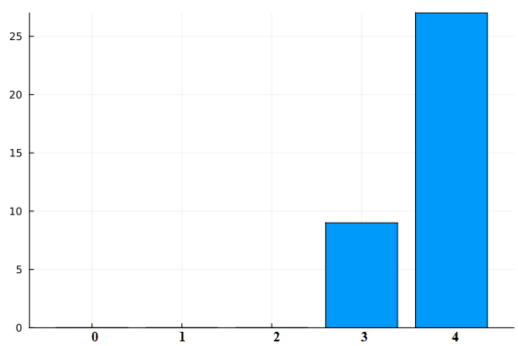

Figure 2: Bar graph with the results of the final evaluative indices in the post-test. The abscissa shows the indices and the ordinate shows the absolute frequency.

According to the results of Figures 1 and 2 the shift in the distribution of frequencies from the pre-test to the post-test, with a higher concentration at the best performance level after the training, indicates that the training program successfully enhanced the students' abilities. This can be seen as a positive outcome of the training intervention.

. To determine if this improvement is significant, we applied the Wilcoxon test, the results of which were the following, according to Table 3:

Z	-5,169[b] -
Asymptotic sig. (bilateral)	0.000

b. Wilcoxon signed rank test

c. It is based on negative ranges.

Table 3: Wilcoxon non-parametric test, for related samples, of the pre-test and post-test scores.

In Table 3, from the non-parametric Wilcoxon statistical test, it is observed that the p-value is $0.00 < 0.05$, allowing us to reject H_0 of the equality of grades means, the obtained grades by the students in the pre- and post-tests (H_0: $\mu_1 = \mu_2$), consequently, there is a highly significant difference in the means of the grades or scores obtained in the pre- and post-test. The post-test group scores are higher than the pre-test scores. Based on the obtained results, consequently, there is statistical evidence to approve Ha (Ha: $\mu_2 > \mu_1$), so, there is a highly significant influence of the "AK guide for forest management" on the learning level of the NUCP Forest Engineering students, after their application.

Conclusion

The "AK guide to forest management" is a pedagogical instrument that collects the knowledge of the Peruvian indigenous people about the vegetation and life in these ecosystems. With this paper we wanted to demonstrate the validity of this knowledge, even today, and that it can complement current scientific knowledge. In the article, a test was carried out on the guide to a group of 36 Forest Engineering students, who studied it. The results of the pre-test were compared with the post-test using the Wilcoxon method of paired samples and the conclusion was that there is a significant improvement in the scientific knowledge of the students who studied the guide. That is why it is considered a valuable teaching instrument for the Forest Engineering career at the National University of Central Peru.

To ensure greater reliability in the results, we used a linguistic scale for the expert to carry out the evaluation, since human beings find it easier to evaluate in linguistic terms than in numbers. This principle was established by Zadeh who called this Computing with words rather than numbers, and an example of a technique is the 2-tuples linguistic method. In our case, we decided to gain greater accuracy with the use of the neutrosophic 2-tuple that allows the evaluator to give linguistic values not only for truthfulness, but also for indeterminacy and falsity, which allows the expert to express his opinion more accurately, and also incorporate inconsistency, contradictions, and ignorance.

Further research is encouraged to refine the neutrosophic 2-tuple linguistic method, potentially incorporating advanced computational techniques such as machine learning to analyze linguistic data more effectively. This could lead to the development of more sophisticated evaluation tools that can capture the complexity and nuance of human judgments in educational assessments.

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Annex

The Annex contains the results of the data collection and the surveys applied.

Student	Pre-test (x_i)	Post-test (y_i)
e_1	3.4	4
e_2	2	2.8
e_3	3.4	4
e_4	3.2	3.8
e_5	1.4	3.6
e_6	2.4	4
e_7	3	4
e_8	3.2	3.8
e_9	3.2	3.8
e_{10}	1.8	2.8
e_{11}	2.6	3.8
e_{12}	2.2	3.8
e_{13}	0.8	3
e_{14}	3	3.4
e_{15}	2.4	4
e_{16}	2.2	3.4

e_{17}	1.8	3.4
e_{18}	1.4	2.6
e_{19}	3.8	4
e_{20}	4	4
e_{21}	2.8	3.8
e_{22}	1.8	3.6
e_{23}	2.2	2.6
e_{24}	3	4
e_{25}	2.4	3.8
e_{26}	2.4	3.8
e_{27}	3	3.8
e_{28}	3	3.8
e_{29}	2.2	3.4
e_{30}	3.2	4
e_{31}	3.4	4
e_{32}	3	3.6
e_{33}	2.2	4
e_{34}	2.2	4
e_{35}	2.2	4
e_{36}	3	4

Table 4: Values of x_i and y_i obtained by each student.

Table 5 shows the questionnaire applied for the pre-test and post-test.

Format 01.
DIAGNOSTIC EVALUATION QUESTIONNAIRE
ASHÁNINKAS KNOWLEDGE GUIDE FOR FOREST MANAGEMENT APPLIED AT NUCP FOREST ENGINEERING STUDENTS"

Fisrt and Second names: Cycle:
Career:

1. Have you heard about ancestral knowledge?
Yes /No
If your answer is Yes. Mention the ancestral knowledge that you know
…… …………
………………………………………………… ……. …………………………………………………………
2. Ashaninka knowledge? Yes /No
If your answer is Yes. Mention the Asháninka knowledge that you know.
……
……………………… …………………………………………………………………………………
3. Is Asháninka knowledge important for Sustainable Forest Management? Yes /No
If your answer is Yes. Comment:
……
……………………… ………………………………………………………………………………………
4. Could Asháninka's knowledge be included in the first stage "negotiation for forest exploitation", required by the competent authority, now SERFOR? Yes /No
5. Forestry exploitation is contemplated in the Forestry and Wildlife Law No. 29763, taking into account the sustainable forest management of forests and wildlife. Should Asháninka knowledge be incorporated into activities such as planning, camp construction, laying down, sectioning, coding, and transportation? Yes /No
6. If your answer is Yes, in what activities should AKs be incorporated? Correct/incorrect
a) Planning,
b) Construction of camps,
c) Lying down,
d) Sectioned,
e) Coding,
f) Transportation,
g) All the mentioned,
h) None
7. Is there a connection or link between biotic and abiotic factors and humans? Yes /No.

8. If your answer is Yes, do you affirm that AKs are born and preserved from this interconnection?
Yes /No
If your answer is Yes, please comment on it
………
………
9. Why do the Asháninkas value their knowledge and apply it in their daily lives? Mark the correct answer.
a) Because they know that they coexist with nature and through knowledge they could carry out activities with a sustainable approach that allows them to conserve and preserve their resources.
b) They are learned from generation to generation
c) For them, nature and all living beings have an owner and they must ask permission to use their resources, this limits their consumption.
d) All are valid
10. The productive activities (hunting, gathering, fishing) of the Asháninkas are carried out for subsistence. With forestry extraction their poverty problems should end, however, the opposite is true. The causes are: Write F if false and T if true.
a) Deterioration of their ecosystems due to forestry extraction activities
b) Loss of the AK, their worldview being forgotten
c) Malpractice of the Forest Engineer
d) Inefficient legislation
e) AKs are not included in the study curricula of Forest Engineering
11. Is the Assembly Minutes a determining document for the commercialization of forestry products?
Yes /No
If your answer is Yes. Comment on the importance of the Communal Assembly Act for the Asháninkas
………
………
12. Is the role that community leaders play in contracting with logging companies decisive? Yes /No
If your answer is Yes, what is your opinion about it?
………
………
13. Is it necessary to revalue AK, taking into account that communities sell their forest resources at negligible prices? Yes /No
If your answer is Yes, say Why?
………
………

Table 5: Questionnaire applied for the pre-test and post-test.

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