Epistemological Conceptions in Teacher Education: A Study with Students from Luanda

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To cite this article:

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Article Info	Abstract
	Epistemology plays an important role in detecting learning difficulties in a given field of knowledge and in directing strategies to eliminate them. This quantitative study aimed to get to know the perceptions of 624 students, related to the nature of science and science teaching and learning. The cross-sectional survey, based on the Inventory of Teacher's Pedagogical & Scientific Beliefs (INPECIP) questionnaire, was applied to the students who attended the 10th, 11th and 12th grades of teacher training courses, in a school in Luanda. The results reveal a clear majority agreement with the theoretical and conceptual frameworks presented, in decreasing manner, from the "didactic model" through the "learning theory", the "image of Science" and the "teaching methodologies". The regression model highlights that the course attended clearly influences the epistemological conceptions of the respondents.

Introduction

Conceptions about conceptions, that is, knowledge about knowledge, are particularly important to favor the transition from simple to complex. Porlán (1993) argues that the degree of complexity of a subject's ideas about the nature of knowledge, its forms of organization and change, and the role they can play in the cognitive system, favor processes of generalization, transfer and integration between partial areas of personal knowledge, both in themselves and in others. Some studies categorically highlight the relationship that exists between the epistemological conceptions that science teachers keep and those that their students develop (Bonito, 2012; Martín del Pozo, 1994; Porlán, 1989; Vazquez, Manassero, García-Carmona, & Montesano, 2016). Teachers' conceptions, particularly those associated with disciplinary epistemology and natural epistemology, play an important role in planning, evaluation and decision-making.

Some studies from the 2000s reveal that students have an absolutist / empirical view of science (Kang, Scharmann, & Nonh, 2005; Kichawen, Swaun, & Monk, 2004). Others, from the same period, point out that the variety of sources of out-of-school information influence the construction of students' conceptions about science, the most important influence being the image transmitted (Dhingra, 2003; Dogan & Abd-El-Khalick, 2008). In this context, cultural factors and socioeconomic and educational levels also seem to have some influence.

Epistemology and the history of science play an important role in detecting learning difficulties in each field of knowledge and in directing strategies to eliminate them (Duschl, 1997; Giordan & Vecchi, 1988), and the identification of epistemological obstacles presents itself as a solution for changing science teaching (Giordan & Vecchi, 1988). Epistemology thus presents itself as a guide for the teaching of science: it assumes an explanatory role on the basic principles adopted by science and on challenging empiricism. Hence, already in the 1980s, Giordan and Vecchi (1988) came to defend that the identification of epistemological obstacles is fundamental for the transformation of science teaching, as they are intrinsic to the knowledge process and constitute themselves as accommodations to what has already been known.

These obstacles can be external or internal in nature and inhibit or hinder scientific development. For Bachelard (1979), it is based on these obstacles that scientific knowledge must be approached, because for learning to happen it is necessary that the student be presented with reasons to evolve. Among the various epistemological obstacles, Bachelard (1977) highlights the tendency to rely on previous knowledge or previous experience, and points out the importance of error.

Recent studies reveal that concrete and targeted didactic interventions promote the progression of students' ideas towards the construction of ideas closer to those desired in science, with the overcoming of several obstacles that result in an erroneous image of science, namely the empiricist, individualistic, immediate idea, absolutist or procedural (Escrivà-Colomar & Rivero-García, 2017). Many works from the 1980s reveal that teachers of basic and secondary education have inadequate conceptions about the nature of science, manifested in a simplified and distorted image, forgetting its historical-philosophical aspects. It is thus expected that this vision will be transferred and will remain with their students.

On the other hand, these teachers' conceptions about science teaching and learning are diverse and influence the way they act in teaching practice. Hashweh's (1996) work already realized that points of view close to constructivism are more likely to use more appropriate approaches to achieve conceptual change and more often use more effective teaching strategies. These teachers tend to positively value these strategies. The aim of this study is to identify the predominant conceptions of students at a teacher training school in Luanda, Angola, related to the nature of science and the teaching and learning of sciences.

Method

Participants

Simple random probabilistic sampling in each class of each course (confidence index = 0.05, sampling error = 5%). 624 students (age = 18.7; STDEV = 3.50, age group 18-22 years). 325 (52,1%) women and 299 (47,8%) man. 164 (18.3%) of History and Geography, 198 (18.6%) of Biology and Chemistry, and 262 (15.2%) of Mathematics and Physics (Table 1).

Table 1. Population and Sample for Each Class and Course

Courses	Classes	Population	Sample $\alpha = 0.05, e = 5\%$ f (%)
Biology and Chemistry	10th	62 (25.3)	54 (27.3)
	11th	52 (21.1)	46 (23.2)
	12th	131 (53.5)	98 (49.5)
Sub-total		*245 (31.2)*	*198 (31.7)*
History and Geography	10th	60 (32.2)	53 (32.3)
	11th	41 (22.0)	41 (25.0)
	12th	85 (45.7)	70 (42.7)
Sub-total		*186 (23.7)*	*164 (26.3)*
Mathematics and Physics	10th	184 (52.0)	125 (47.7)
	11th	121 (34,2)	93 (35.5)
	12th	49 (13.8)	44 (16.8)
Sub-total		*354 (45.1)*	*262 (42.0)*
TOTAL		*785*	*624*

Information Collection Instruments

Cross-sectional data collection was carried out by applying a questionnaire adapted from the Inventory of Teacher's Pedagogical & Scientific Beliefs (INPECIP) questionnaire, by Porlán (1989), with four dimensions, each with 14 items: nature of science, learning theories, didactic models and teaching methodologies. The version of INPECIP used resulted from the translation, adaptation, and restructuration of the original matrix to fit the reality of Angola, having been submitted to the appreciation of a panel of expert judges, made up of two university professors in the area of Educational Sciences. The analysis of these judges resulted in the identification of some weaknesses, namely problems of understanding, which contributed to a new wording of some statements. After integrating the suggestions pointed out by the panel of judges, a pilot questionnaire was applied to a teacher from another educational institution, that teaches at the teacher training level. It was noticed that this individual did not reveal any doubts filling the questionnaire. This sequence of procedures resulted in the final version.

The order in which the items in the questionnaire appeared was determined at random, using a table of random numbers. This procedure aimed to avoid groupings by category, to prevent the importance of one statement from being considerably influenced by another. Respondents were asked to express their degree of disagreement and agreement with the statements of INPECIP, using a Likert scale for this purpose: total disagreement, disagreement, do not know / undecided, agreement, total agreement. If we consider the set of 56 items that make up the variable epistemological conceptions, the determined reliability is between moderate to high, with an average value of Cronbach's alfa = 0.812.

Procedure

The first contacts with the school took place in October 2015. The project was presented to the director and his acceptance and agreement for the study in that educational institution was collected. Teachers from classes in the 10th, 11th and 12th grades were contacted. Before the distribution of the questionnaires, the objectives of the study were presented and the importance of the work regarding the improvement of the teaching practices and the consequent gains in student's learning was explained. The questionnaires were applied between June 2, 2016 and January 3, 2017.

In the development of the work, the ethical principles of research in Social Sciences were respected. All respondents signed an informed consent form to participate in the study. Anonymity has been preserved. The collected information was treated and analyzed using descriptive and inferential statistics.

Results and Discussion

Science Image

The results reveal that 78.5% agrees with the items presented regarding the image of science. In this dimension, 11.4% of students expressed their indecision / lack of knowledge. The modal class is "agreement" (see Figure 1).
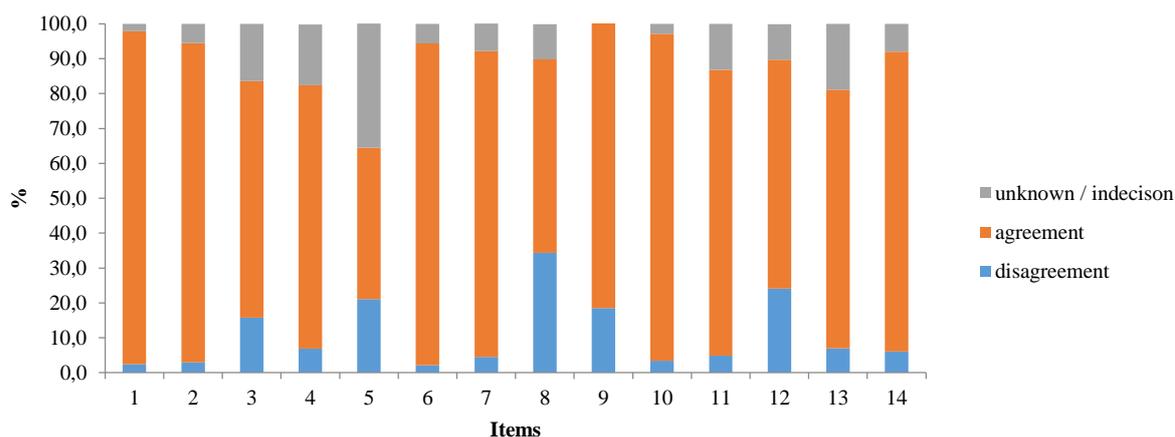
Figure 1. Conceptions about the Image of Science, Conveyed by Students

The three statements that bring together the greatest consensus, at the level of agreement, with 95.5% and 93.7% and 92.3% of choices, respectively, are: item 1 ("All scientific research begins with the systematic observation of the phenomenon being studied"), item 10 ("The researcher tests the truth or falsehood of the working hypothesis through experiment") and item 6 ("The effectiveness and objectivity of scientific work resides in following faithfully the ordered phases of the scientific method: observation, hypothesis, experiment, and construction of theories"). Item 5 ("In the observation of reality, it is impossible to avoid a certain degree of distortion introduced by the observer"), of a rationalist nature, is the only one that brings together a percentage

of agreement below 50% (43.4%). The highest percentage of total agreement response is recorded in item 10 (70.0%), while the maximum value for the simple agreement is attributed to item 11 ("The research process is directed by hypotheses") (44.3%).

Item 8 ("The scientific observer should not act under the influence of previous theories about the problem being studied") is the one that gathers the greatest disagreement choices (55.4%), registering the highest values for the total disagreement option (35.9%) and of simple disagreement (19.5%). All other items receive global disagreements with values below 24.1%. Items 6 and 1 have the lowest rate of disagreement, respectively 2.1% and 2.4%. The highest value for total disagreement is found in item 8. Overall, dimension I ("image of Science") gathered 78.5% agreement and 11.0% disagreement. The average percentage of indecision is 11.4%, higher than the average of disagreement by 0.4 points. Item 5 was the one that created the greatest instability at the time of the decision, gathering 35.6% of undecided answers. Item 1is the one that is most secure with the least indecision among respondents (2.1%).

The analysis of these results makes it possible to identify the levels of formulation on the image of science that students highlight. These perspectives reveal that to obtain scientific knowledge it is necessary to resort to the scientific method, as a rigid and objective procedure. When it is considered that through experience the researcher proves whether his working hypothesis is true or false (95.5%), an empiricist-experimentalist tendency is revealed. Previous theories are considered important for the observer to base their actions on. The results reveal indecision as to the degree of deformation that the observer introduces, inferring a weakness in the logical rigor of formulating the image of Science.

The results reveal that students and teachers tend to manifest that human knowledge is the product of the interaction between thought and reality, in line with what Bunge teaches (1980), who argues that in scientific knowledge and common knowledge there is an intended rationality and objectivity and that there is a relationship of continuity and discontinuity between them. The importance of establishing hypotheses in the scientific investigation process is recognized, but they tend to disagree that the observer should not act under the influence of previous theories, which agrees with the ideas of Oizerman (1976), when referring that concepts and evidence are debatable.

Personal Didactic Model

The results reveal that 89.3% of the respondents agree with the items presented in relation to the personal didactic model. In this dimension, 6.5% express their indecision / ignorance. The modal class is "full agreement" (see Figure 2).
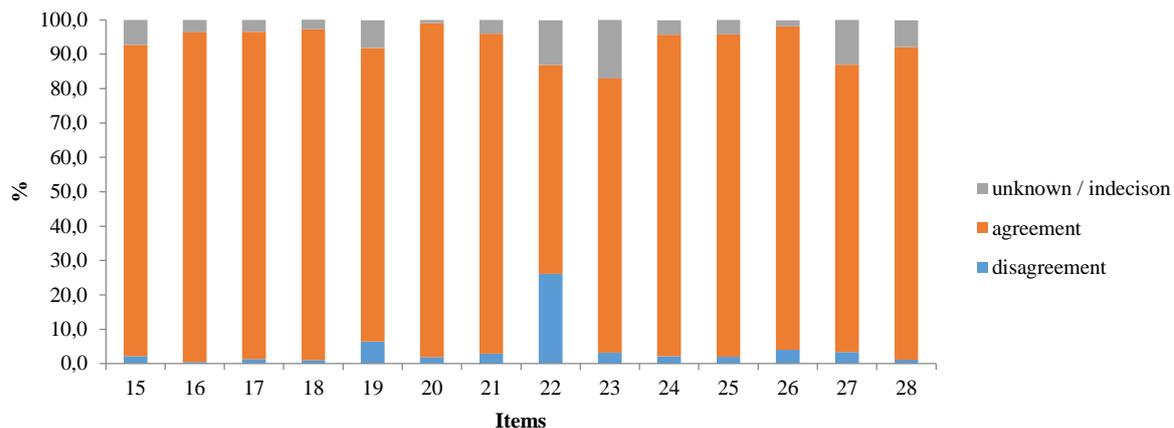
Figure 2. Conceptions about the Personal Didactic Model, Conveyed by Students

Ten items welcomed greater agreement preference, the four largest being, with frequencies greater than 95%, namely: item 20 ("The teacher must plan in full detail the tasks to be done in class by the teacher and the students to avoid improvisation") (97.1%), item 18 ("The basic objective of Didactics is to define the techniques that are most appropriate for quality teaching") (96.3%), item 16 ("Didactics has to define principles and norms to guide and orient educational practice") (95.8%) and item 17 ("The aim of Didactics is to describe and understand the teaching-learning processes that take place in the classroom") (95.2%). The consideration that the teaching-learning processes that take place in every class are complex phenomena involving innumerable factors (item 27) was the item that gathered the greatest consensus of total agreement (47.3%), despite item 20 had gathered the highest percentage of simple agreement (82.5%). Overall, the agreement rate is 56.2% and the total agreement rate is 33.1%.

In this dimension, the average degree of disagreement with the theoretical framework presented is considered low (4.2%), with a maximum value of 26.1% registered in item 22 ("The students should intervene directly in the programming and evaluation of the activities in class") and a minimum value of 0.5% in item 16 ("Didactics has to define principles and norms to guide and orient educational practice").

The greatest lack of knowledge / the greatest indecision is obtained with item 23 ("Organized and hierarchized objectives should constitute the essential instrument guiding educational practice") (17.0%). Few doubts arise related to item 20, about the teacher's mission to plan, in detail, the tasks to be performed in class to avoid improvisation (1.0% ignorance). The dimension's modal value is 5 ("Total agreement"). The recognition of the importance of a detailed planning carried out by the teacher is in line with that advocated by literature, namely by Rosário, Ferreira, and Guimarães (2001).

Learning Theories

The results show that 87.1% of the respondents agree with the items presented in relation to the personal didactic model. In this dimension, 6.7% expressed their indecision / lack of knowledge. The modal class is "full agreement" (see Figure 3).
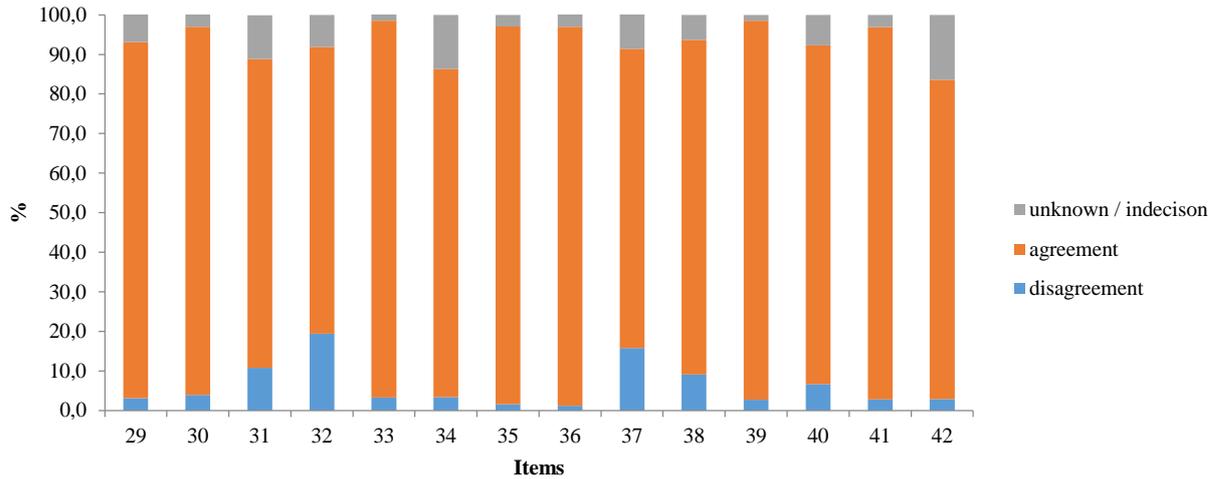
Figure 3. Conceptions about Learning Theories, Conveyed by Students

This dimension registers four items with agreement values greater than 95%: items 36 ("Scientific learning is meaningful when the students find a personal interest in what they are learning") and 39 ("Conceptual errors should be corrected by explaining the correct interpretation as often as the student needs"), *ex aequo* (95.8%); item 35 ("Learning is improved if the students relate the new content to their previous knowledge") (95.5%) and item 33 ("Science learning takes place when the teacher explains a scientific concept with clarity and the student is paying attention") (95.2%). No proposition registers a value below 72.5%, found in item 32, "The students have the capacity to form conceptions about the natural and social world spontaneously, by themselves".

The item that gathered the greatest consensus of total agreement is 34 ("The science learning that is essential for the students to assimilate in school is that which is related to the comprehension of concepts"), with 55.8% of choices, with item 33 gathering the simple agreement of 71.9% of the respondents.

If attention is drawn to disagreements with the theoretical framework, it appears that the maximum value did not exceed 19.4 percentage points, recorded in item 32. The item that generates the least disagreement is that science learning is significant when the student has a personal interest related to what he learns (item 36) (1.2%), relating to item 35, which brought together only 0.2% of total disagreement. The average global disagreement is 6.2%, 5 percentage points lower than ignorance and / or indecision.

The students' personal interest in the contents (item 36) is referred being important for learning in agreement with the literature (Bonito et al., 2009; Porlán, 1989; Rebelo & Marques, 2000). The reference to the relevance of previous concepts for learning also meets the authors studied (Ausubel, Novak, & Hanesian, 1978; Pearson, 1984; Sousa, Silvano, & Lima, 2018). Respondents reveal a line of thought close to a constructivist theory, but a contrast is revealed that argues that the learning processes are related to the transmission-reception binomial, in this perspective learning the appropriation of meanings produced by a subject external to the one who learns.

Teaching Methodologies

The results show that 77.9% of the answer agrees with the items presented in relation to teaching methodologies. In this dimension, 11% express their indecision / lack of knowledge, the highest of the values recorded in the four categories. The modal class is "full agreement" (see Figure 4).
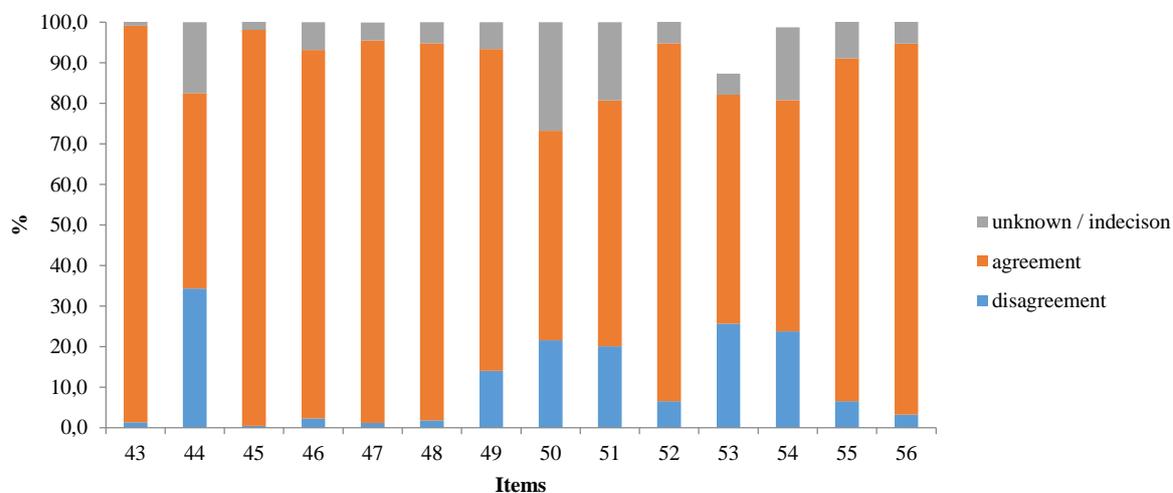
Figure 4. Conceptions about Teaching Methodologies, Conveyed by Students

In this dimension, two propositions register global agreement values above 97%, the item 43, "The students learn scientific concepts correctly when they do practical activities", (97.8%) and the item 45, "To teach science, it is necessary to explain the topics without hurrying, so as to facilitate learning" (97.6%), accompanied by another 4 propositions that have relative frequencies above 90 percentage points. The lowest global agreement is verified with item 44, "Doing problems in class is the best alternative to the traditional master-pupil method of teaching science" (48.2%). If attention is drawn to the agreement and the total agreement in isolation, items 54 ("Science teaching based on spoken explanation of the topics encourages the students' rote learning of the content") (19, 2%) and 53 ("Most science textbooks do not facilitate comprehension and learning") (20.3%) are found.

Item 44 is the one that brings together the greatest global disagreement among respondents (34.3%). About 57% of the items recorded relative frequencies equal to or less than 8.5 percentage points of global disagreement, with the lowest value (0.5%) found in item 45. The average global disagreement is 11.6% in this dimension.

Considering that each of the 4 categories of the questionnaire, related to epistemological conceptions, presents a set of 14 questions, the variables were analyzed in an aggregate way. Items 1-14, 15-28, 29-42 and 43-56 were combined into four new variables (Cat_1; Cat_2; Cat_3; Cat_4), which correspond to the questionnaire categories (see Table 2). Then, normality tests were performed for the aggregated variables (see Table 3).

Table 2. Aggregate Analysis of the New Variables

Variable	n	$\overline{X}$ (STDEV)*	$\tilde{X}$*	Min*	Max*	IQR*
Cat_1	435	4.07 (0.38)	4.07	2.86	5.00	0.43
Cat_2	435	4.43 (0.33)	4.43	3.43	5.00	0.43
Cat_3	435	4.36 (0.38)	4.36	3.00	5.00	0.57
Cat_4	435	3.86 (0.38)	3.86	2.79	5.00	0.43

* $\overline{X}$ (STDEV) – average (standard deviation). $\tilde{X}$* – median. Min – minimum. Max – maximum. IQR – interquartile range.

Table 3. Normality Tests for Aggregate Variables

Variable	n	KS test*		Shapiro-Wilk test	
		Statistic	p-value	Statistic	p-value
Cat_1	435	0.059	0.001	0.991	0.008
Cat_2	435	0.085	0.000	0.977	0.000
Cat_3	435	0.078	0.000	0.968	0.000
Cat_4	435	0.059	0.001	0.993	0.032

KS test*: Kolmogorov-Smirnov test with Lilliefors correction.

All p-values are less than 0.05, leading to the rejection of the null hypothesis, that the variables may come from normal distributions. In a more detailed analysis, we tried to analyze whether there are statistically significant differences (for each of the new variables) depending on the variables "sex", "age", "academic qualifications - course" and "academic qualifications - year". This analysis is explained in detail only for the first factor considered, the sex of the participants. For the remaining variables, namely, "age", "academic qualifications - course" and "academic qualifications - year", only the conclusions are presented in text, the statistical analysis output tables being presented in Annex. Regarding the variable "sex", given the p-values obtained (see Table 4), the Kolmogorov-Smirnov test with Lillifors correction, and the Shapiro-Wilk test, point to the rejection of the null hypothesis of normality (except for male classes for the variables Cat_1 and Cat_4). Therefore, comparisons between classes should be performed in a non-parametric context, using the Mann-Whitney U test (see Table 5). The same conclusion can be drawn by making the analysis excluding pairwise cases.

Table 4. Normality Tests across Groups of Variable "Sex" in the Aggregate Variables

Variable	Classes	n	KS test*		Shapiro-Wilk test	
			Statistic	p-value	Statistic	p-value
Cat_1	Male	214	0.074	0.006	0.987	0.052
	Female	221	0.096	0.000	0.983	0.008
Cat_2	Male	214	0.095	0.000	0.973	0.000
	Female	221	0.085	0.001	0.977	0.001
Cat_3	Male	214	0.075	0.005	0.968	0.000
	Female	221	0.089	0.000	0.964	0.000
Cat_4	Male	214	0.066	0.025	0.992	0.286
	Female	221	0.079	0.002	0.986	0.029

Table 5. Mann-Whitney U Test for Crossing the "Sex" Variables with the New "Categories"

Variable	Class	n	Average (STDEV)	Me	Mann-Whitney U test	Averages comparison t test
Cat_1	Male	251	4.10 (0.40)	4.14	0.009*	0.032*
	Female	270	4.02 (0.38)	4.00		
Cat_2	Male	279	4.41 (0.36)	4.43	0.860	0.881
	Female	293	4.41 (0.36)	4.43		
Cat_3	Male	279	4.31 (0.38)	4.36	0.380	0.518
	Female	296	4.33 (0.42)	4.36		
Cat_4	Male	266	3.86 (0.37)	3.86	0.651	0.608
	Female	289	3.84 (0.41)	3.86		

Although the most appropriate test for performing comparisons between classes is the Mann-Whitney U test, the result of the t test of comparison of means (also show in Table 5) is always in agreement with the first, at the significance level of 0.05. Differences between medians (or averages) between men and women are only considered significant for the variable Cat_1. To test whether the median (or average) of the male class can be considered significantly higher than the median of the female class, one just must divide the bilateral p-value shown in the table by two, since the p-value sought is the one which corresponds to the test whose alternative hypothesis is in accordance with the sample trend. Therefore, since the unilateral p-value obtained is less than 0.05 for both the Mann-Whitney U test and the t test), it can be concluded that the median (or the average) of the male class should be significantly higher than the median (or the average) of the female class, with respect to the variable Cat_1.

Regarding the variable "age", according to the p-values obtained for the Shapiro-Wilk test (Table A.1), only comparisons between classes related to the variable Cat_4 can be performed in a parametric context, by performing of an ANOVA. Comparisons between classes for the remaining variables should be performed in a non-parametric context, using the Kruskal-Wallis test. According to the Kolmogorov-Smirnov test with Lilliefors correction, all multiple comparisons must be performed in a non-parametric context (Table A.2). Doing the analysis with the of pairwise exclusion cases, all multiple comparisons must also be performed in a non-parametric context. Although, in the case of the variables Cat_1 and Cat_2, multiple comparisons must be performed in a non-parametric context, the results are consistent for the Kruskal-Wallis test and for the parametric ANOVA parametric (also show in Table A.2). Therefore, it may be considered that, regarding the variables Cat_1 and Cat_2, the differences between the classes of the variable "age" should be significant. Looking at the multiple comparisons, in a non-parametric context, by performing all possible comparisons between pairs with the Mann-Whitney U test (results shown in Table A.3), it can be said that at the 0.05 significance level, there are reasons to consider that:

• For the Cat_1 variable, the median of Class 3 (variable "age") is significantly higher than the median of Class 1 (variable "age");

• For the variable Cat_2, the median of Class 4 (variable "age") is significantly higher than the median of Class 1 (variable "age");

• For the variable Cat_2, the median of Class 4 (variable "age") is significantly higher than the median of Class 2 (variable "age").

Regarding the variable "Academic qualifications – Course", the normality tests are presented in Table. A.4, and according to the result of both tests, all multiple comparisons must be performed in a non-parametric context (Table A.5). Although, for all variables Cat_1, Cat_2, Cat_3 and Cat_4, multiple comparisons must be performed in a nonparametric context, the results are consistent for the Kruskal-Wallis test and for the parametric ANOVA. We can then consider that, for the variables Cat_1, Cat_2 and Cat_3, the differences between the classes of the variable "Academic Qualifications - Course" should be significant. Proceeding to the performance of multiple comparisons, in a non-parametric context, by performing all possible comparisons between pairs with the Mann-Whitney U test (results shown in Table A.6), at the 0.05 significance level, there are reasons to consider:

a) For the Cat_1 variable, the median of Class 3 (variable "academic qualifications - course") is significantly higher than the median of Class 1 (variable "academic qualifications - course");

b) For the variable Cat_2, the median of Class 3 (variable "academic qualifications - course") is significantly higher than the median of Class 1 (variable "academic qualifications - course);

c) For the variable Cat_3, the median of Class 2 (variable "academic qualifications - course") is significantly higher than the median of Class 1 (variable "academic qualifications - course");

d) For the variable Cat_3, the median of Class 2 (variable "academic qualifications - course") is significantly higher than the median of Class 3 (variable "academic qualifications - course").

Normality tests for variable "Academic qualifications – Year" are presented in Table A.7, and, according to these results all multiple comparisons must be performed in a non-parametric context (Table A.8). Although, for all variables Cat_1, Cat_2, Cat_3 and Cat_4, multiple comparisons must be performed in a nonparametric context, the results are consistent for the Kruskal-Wallis test and for the parametric ANOVA. We can then consider that, for all variables Cat_1, Cat_2, Cat_3 and Cat_4, the differences between the classes of the variable "academic qualifications - year" should be significant. Performing all possible comparisons between pairs with the Mann-Whitney U test, in a non-parametric context, (Table A.9), it can be concluded that, at the 0.05 significance level, there are reasons to believe that:

a) For the variable Cat_1, the median of Class 2 (variable "academic qualifications - year") is significantly higher than the median of Class 1 (variable "academic qualifications - year");

b) For the variable Cat_1, the median of Class 2 (variable "academic qualifications - year") is significantly higher than the median of Class 3 (variable "academic qualifications - year");

c) For the variable Cat_2, the median of Class 2 (variable "academic qualifications - year") is significantly higher than the median of Class 1 (variable "academic qualifications - year");

d) For the variable Cat_2, the median of Class 2 (variable "academic qualifications - year") is significantly higher than the median of Class 3 (variable "academic qualifications - year");

e) For the variable Cat_3, the median of Class 1 (variable "academic qualifications - year") is significantly higher than the median of Class 3 (variable "academic qualifications - year");

f) For the variable Cat_4, the median of Class 1 (variable "academic qualifications - year") is significantly

higher than the median of Class 3 (variable "academic qualifications - year");

g) For the variable Cat_4, the median of Class 2 (variable "academic qualifications - year") is significantly higher than the median of Class 3 (variable "academic qualifications - year").

To determine the variables under study ("sex", "academic qualifications - course" and "academic qualifications - year") that prove to be predictors of epistemological conceptions (EC), a logistic regression model was tested. The EC variable was created at the expense of the sum of the variables Cat_1, Cat_2, Cat_3 and Cat_4, with an equal weighting coefficient. Given the high collinearity between the variable EC and all of the variables Cat_1, Cat_2, Cat_3 and Cat_4, none of the later can be included as a predictor variable in this model. The EC variable was transformed in the sense of taking values on a continuous scale as expected according to the classical linear regression model. The output obtained was as follows (Table 6):

Table 6. Logistic Regression Model for the Variable "Epistemological Conceptions" (EC)

Parameters	Non-standardized coefficients		Hypothesis Testing	
	β	Standard error	Statistics t	p-value
Constant	2.448	0.013	184.853	< 0.001***
Factor (sex = 1)	0[a]	-	-	-
Factor (sex = 2)	0.003	0.010	0.260	0.795
Factor (course = 1)	0[a]	-	-	-
Factor (course = 2)	0.032	0.013	2.574	0.010*
Factor (course = 3)	0.009	0.012	0.746	0.456
Factor (year = 1)	0[a]	-	-	-
Factor (year = 2)	0.018	0.012	1.538	0.125
Factor (year = 3)	-0.028	0.012	-2.457	0.014*

Dependent variable: EC (Modified). Model: (Intercept), Sex, Course, Year. A - Level 1 of each factor variable is defined as the reference level. Set to zero because this parameter is redundant. * Significant correlation ($0.01 <$ p-value< 0.05); ** Very significant correlation ($0.001 <$ p-value< 0.01); *** Highly significant correlation (p-value< 0.001).

The determination coefficient and the adjusted determination coefficient were obtained for this model, giving, respectively, $R^2 = 0.047$ and $R^2 = 0.036$, values that can be considered very low and consistent with a low explanatory power of the model. However, all the predictor variables included in the model are categorical in nature, which contributes to greatly reducing the mentioned determination coefficients. Also, the evaluation of the global significance of the regression model by performing an ANOVA results in a p-value = 0.0009233, which means that the model has statistical significance. Regarding the assumptions of the regression model, normality can only be assumed at a significance level of 0.001, according to the Kolmogorov-Smirnov test with Lilliefors correction (p-value = 0.01002) or according with the Shapiro-Wilk test (p-value = 0.001288).

The estimated equation for this model is given by:

EC = 2.448 + 0.003 sex (2) + 0.032 course (2) + 0.009 course (3) + 0.018 year (2) − 0.028 year (3)

Then, the association between the variables Cat_1, Cat_2, Cat_3 and Cat_4 was investigated. Since the variables involved are on a continuous scale (but result from the aggregation of variables that were on an ordinal scale) to test the correlation between them, we can use two measures, both suitable in this situation (and whose associated non-parametric tests are more powerful than the Chi-Square test, valid for testing the existence of correlation between categorical variables). These measures are Kendall's tau b correlation coefficient and Spearman's rho correlation coefficient (see Table 7 and Table 8).

Table 7. Nonparametric Correlations (Kendall's tau_b)

		Cat_1	Cat_2	Cat_3	Cat_4
Cat_1	Coefficient	1	0.408	0.297	0.270
	p-value	-	0.001**	0.001**	0.001**
	n	522	493	493	477
Cat_2	Coefficient		1	0.417	0.298
	p-value		-	0.001**	0.001**
	n		573	538	518
Cat_3	Coefficient			1	0.390
	p-value			-	0.001**
	n			576	530
Cat_4	Coefficient				1
	p-value				-
	n				555

* Significant correlation ($0.01 < $ p-value $ < 0.05$); ** Very significant correlation ($0.001 < $ p-value $ < 0.01$); *** Highly significant correlation (p-value $ < 0.001$).

Table 8. Nonparametric Correlations (Spearman's rho)

		Cat_1	Cat_2	Cat_3	Cat_4
Cat_1	Coefficient	1	0.548	0.407	0.372
	p-value	-	0.001**	0.001**	0.001**
	n	522	493	493	477
Cat_2	Coefficient		1	0.562	0.413
	p-value		-	0.001**	0.001**
	n		573	538	518
Cat_3	Coefficient			1	0.530
	p-value			-	0.001**
	n			576	530
Cat_4	Coefficient				1
	p-value				-
	n				555

* Significant correlation ($0.01 < $ p-value $ < 0.05$); ** Very significant correlation ($0.001 < $ p-value $ < 0.01$); *** Highly significant correlation (p-value $ < 0.001$).

Conclusions

The students' image of Science varies between a rationalist and an empiricist view. In a finer analysis, conceptions relate to a model of epistemological relativism, which considers scientific knowledge as a product of the interaction between thought and reality, defending the limitations of rationalism and significantly less those of empiricism. The scientific methodology approach is not adopted in its entirety, fulfilling all its stages. The role of observation is highlighted. The objectivity of the scientific method is considered. The association of knowledge and appropriation of the world, because of reflection-action, is not strengthened. Ordinary knowledge and scientific knowledge are clearly distinguished despite being read with conceptual weaknesses. As for the role of error in science, students associate it with the dynamic character of Science considering that what is accepted at a given moment may stop being sometime later. The error is also understood as a starting point for new theories and, as a result, plays an important role in the advancement of Science.

The results reveal that a personal didactic model approached the state of the art. Didactics is seen as a scientific discipline, which carried out theoretical-practical research, however, above all with a descriptive and normative character. In a finer analysis, Didactics is considered in a different way and tends to be defined as the technique of stimulating, directing, guiding the course of learning in the formation of the individual and as the path that leads the teacher to know various methods that can be used in the process of teaching and learning. The complex character of the class is recognized; therefore, the teacher must plan, in detail, the tasks to be performed, and the lesson plans are recognized as being very important for the teaching-learning processes that take place in the classroom.

Students argue that teachers should make teaching tasks compatible with those of investigation into the processes that take place in their classes; however, the student's role is the subject of divergence. Most believe that students should, in general, intervene directly in the programming and evaluation of the activities in class. The teacher has the guiding role in the teaching and learning processes by resorting to oral questions and dialogue with students. The class should be active and allow students to participate.

Work is carried out in the sense of uniformity, attending to different ethnicities and contributing to the acceptance of diversity. Adaptations are made in language and exercises, contextualizing the environment and students' experiences and transdisciplinary approaches are adopted. Motivation is recognized as a contribution to learning and it is argued that it should be maintained throughout the lesson, as it makes it dynamic and appealing. Theory tends to apply to practice.

The concept of learning is considered as a process by which the student appropriates knowledge under the guidance of the teacher and assimilates it. It is also considered a new pattern and a new way of perceiving, more or less consciously, of thinking and acting. It is the basis of the teaching and learning processes, knowing how to elaborate information, analyzing, comparing, generalizing, synthesizing, abstracting, considering that learning is significant when one is able to apply knowledge in new situations. The role of memory is valued.

It is exposed that the strategies used aim at the active participation of all students. The teacher appears as an advisor who resorts to debates, discussion and dialogue. Differentiated strategies are adopted. Expertise is a process that is not acquired quickly. To develop dexterity, it is necessary for the student to perform many laboratory practices, application exercises using formulas, definitions, and interpretations. It is manifested that social problems, health problems of students, lack of materials and numerous classes hinder the teaching process and expertise.

The importance of monitoring students' individual learning is defended. However, this monitoring is not easy when there is a high number of students per class. The monitoring of students' learning takes place through written tests, oral tests, and group work, using control questions, through daily exercises, tasks and differentiated attention.

Problem solving tends not to be worked on. Several teaching models adopted by teachers are presented, with the constructivist model being the most common.

In summary, there is a clear majority agreement, declared in the questionnaire, with the theoretical and conceptual frameworks presented. The degree of global agreement goes down from the "didactic model" (89.3%), to the "learning theory" (87.1%), the "image of science" (78.5%) and the "methodologies of teaching" (77.9%).

Acknowledgements

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Annex.

Statistical Analysis Outputs for Group Differences

Table A.1 Normality Tests across Groups of Variable "Age" in the Aggregate Variables

Variable	Classes	n	KS test*		Shapiro-Wilk test	
			Statistic	p-value	Statistic	p-value
Cat_1	≤ 17	178	0.098	0.000	0.974	0.002
	18-22	210	0.071	0.011	0.986	0.033
	23-27	31	0.124	> 0.200	0.979	0.795
	≥ 28	8	0.272	0.084	0.838	0.072
Cat_2	≤ 17	178	0.093	0.001	0.978	0.006
	18-22	210	0.098	0.000	0.973	0.000
	23-27	31	0.145	0.097	0.934	0.058
	≥ 28	8	0.159	> 0.200	0.979	0.958
Cat_3	≤ 17	178	0.087	0.002	0.967	0.000
	18-22	210	0.076	0.005	0.971	0.000
	23-27	31	0.144	0.101	0.923	0.029
	≥ 28	8	0.173	> 0.200	0.897	0.272
Cat_4	≤ 17	178	0.074	0.020	0.988	0.139
	18-22	210	0.065	0.029	0.993	0.409
	23-27	31	0.083	> 0.200	0.984	0.914
	≥ 28	8	0.225	> 0.200	0.948	0.690

Table A.2 Kruskal-Wallis Test for Crossing the "Sex" Variables with the New "Categories"

Variable	Class	n	Average (STDEV)	Me	Kruskal-Wallis test	Parametric ANOVA
Cat_1	≤ 17		4.05 (0.37)	4.00		
	18-22		4.05 (0.41)	4.07		
	23-27	511	4.22 (0.40)	4.21	0.037*	0.034*
	≥ 28		4.21 (0.35)	4.07		
Cat_2	≤ 17		4.41 (0.32)	4.43		
	18-22	557	4.39 (0.39)	4.43	0.013*	0.021*
	23-27		4.52 (0.36)	4.57		
	≥ 28		4.64 (0.26)	4.64		

	≤ 17		4.35 (0.36)	4.36		
	18-22		4.29 (0.44)	4.29		
Cat_3	23-27	560	4.42 (0.36)	4.43	0.201	0.116
	≥ 28		4.37 (0.38)	4.36		
	≤ 17		3.82 (0.36)	3.86		
	18-22		3.84 (0.40)	3.86		
Cat_4	23-27	542	3.94 (0.40)	3.93	0.242	0.076
	≥ 28		4.06 (0.50)	3.96		

Table A.3 Multiple Comparisons in a Non-parametric Context for the Variables Cat_1 and Cat_2

Variable	Comparisons between classes	Bilateral p-value[a]	Unilateral p-value[b]
	1-2	1.000	0.500
	1-3	0.044*	0.022*
	1-4	1.000	0.500
Cat_1	2-3	0.136	0.068
	2-4	1.000	0.500
	3-4	1.000	0.500
	1-2	1.000	0.500
	1-3	0.157	0.079
	1-4	0.074	0.037*
Cat_2	2-3	0.206	0.103
	2-4	0.090	0.045*
	3-4	1.000	0.500

Bilateral p-value[a]: p-value provided by the Mann-Whitney U test, with the Bonferroni correction, for the bilateral median comparison test. Unilateral p-valuel[b]: p-value provided by the Mann-Whitney U test, with Bonferroni correction, for the unilateral test whose alternative hypothesis is in accordance with the sample trend (see previous table where the averages and medians of each class are shown). Classes identified with numbers 1, 2, 3 and 4 in Table A.2 correspond to age ranges ≤ 17, 18-22, 23-27 and ≥ 28, respectively.

Table A.4 Normality Tests across Groups of Variables "Academic Qualifications - Course" in the Aggregate Variables

Variable	Class	n	KS test*		Shapiro-Wilk test	
			Statistic	p-value	Statistic	p-value
	HG	125	0.066	> 0.200	0.88	0.355
Cat_1	BCH	122	0.082	0.041	0.978	0.046
	MPH	188	0.067	0.039	0.990	0.234

	HG	125	0.104	0.002	0.968	0.004
Cat_2	BCH	122	0.074	0.096	0.987	0.288
	MPH	188	0.105	0.000	0.974	0.002
	HG	125	0.101	0.003	0.965	0.003
Cat_3	BCH	122	0.149	0.000	0.909	0.000
	MPH	188	0.079	0.007	0.981	0.011
	HG	125	0.068	> 0.200	0.981	0.080
Cat_4	BCH	122	0.112	0.001	0.970	0.008
	MPH	188	0.074	0.013	0.986	0.053

HG = Class 1 (History and Geography); BCH = Class 2 (Biology and Chemistry) and MPH = Class 3 (Mathematics and Physics).

Table A.5 Kruskal-Wallis Test to Cross the Variables "Academic Qualifications - Course" with the New "Categories"

Variable	Class	n	Average (STDEV)	Me	Kruskal-Wallis test	Parametric ANOVA
	HG		4.01 (0.43)	4.00		
Cat_1	BCH	522	4.03 (0.37)	4.00	0.043*	0.041*
	MPH		4.11 (0.38)	4.07		
	HG		4.33 (0.42)	4.43		
Cat_2	BCH	573	4.42 (0.36)	4.43	0.008*	0.002*
	MPH		4.46 (0.31)	4.50		
	HG		4.24 (0.40)	4.29		
Cat_3	BCH	576	4.45 (0.43)	4.57	< 0.001***	< 0.001***
	MPH		4.31 (0.36)	4.29		
	HG		3.82 (0.46)	3.79		
Cat_4	BCH	555	3.88 (0.37)	3.93	0.169	0.355
	MPH		3.84 (0.34)	3.86		

HG = Class 1 (History and Geography); BCH = Class 2 (Biology and Chemistry) and MPH = Class 3 (Mathematics and Physics).

Table A.6 Multiple Comparisons in a Non-parametric Context for the Variables Cat_1, Cat_2 and Cat_3

Variable	Comparisons between classes	Bilateral p-value[a]	Unilateral p-value[b]

		Bilateral p-value	Unilateral p-value
	1-2	1.000	0.500
Cat_1	1-3	0.082	0.041*
	2-3	0.141	0.071
	1-2	0.319	0.160
Cat_2	1-3	0.005*	0.003*
	2-3	0.624	0.312
	1-2	0.000***	0.000***
Cat_3	1-3	0.696	0.348
	2-3	0.000***	0.000***

Bilateral p-value[a]: p-value provided by the Mann-Whitney U test, with Bonferroni correction, for the bilateral median comparison test. Unilateral p-value[b]: p-value provided by the Mann-Whitney U test, with Bonferroni correction, for the unilateral test whose alternative hypothesis is in accordance with the sample trend (see previous table where the averages and medians of each class are shown).

Table A.7 "Normality Tests across Groups of Variables "Academic Qualifications - Year" in the Aggregate Variables

Variable	Class	n	KS test*		Shapiro-Wilk test	
			Statistic	p-value	Statistic	p-value
	10th	164	0.106	0.000	0.974	0.004
Cat_1	11th	119	0.062	> 0.200	0.986	0.256
	12th	152	0.079	0.021	0.977	0.013
	10th	164	0.117	0.000	0.964	0.000
Cat_2	11th	119	0.080	0.057	0.975	0.025
	12th	152	0.111	0.000	0.967	0.001
	10th	164	0.146	0.000	0.953	0.000
Cat_3	11th	119	0.093	0.014	0.974	0.022
	12th	152	0.111	0.000	0.956	0.000
	10th	164	0.109	0.000	0.981	0.022
Cat_4	11th	119	0.057	> 0.200	0.990	0.542
	12th	152	0.070	0.064	0.984	0.080

Table A.8 Crossing of the Variables "Academic Qualifications - Year" with the New "Categories" in a Non-parametric Context

Variable	Class	n	Average (STDEV)	Me	Kruskal-Wallis test	Parametric ANOVA

Variable						
Cat_1	10th		4.04 (0.39)	4.00		
	11th	522	4.16 (0.40)	4.14	< 0.001***	< 0.001***
	12th		3.99 (0.38)	4.00		
Cat_2	10th		4.40 (0.32)	4.43		
	11th	573	4.47 (0.38)	4.50	0.023*	0.037*
	12th		4.38 (0.38)	4.43		
Cat_3	10th		4.40 (0.36)	4.43		
	11th	576	4.30 (0.44)	4.36	0.003*	0.001*
	12th		4.26 (0.39)	4.29		
Cat_4	10th		3.86 (0.36)	3.93		
	11th	555	3.91 (0.43)	3.93	0.006*	0.010*
	12th		3.78 (0.39)	3.79		

Table A.9 Multiple Comparisons in a Non-parametric Context for the Variables Cat_1, Cat_2, Cat_3 and Cat_4

Variable	Comparisons between classes	Bilateral p-value[a]	Unilateral p-value[b]
Cat_1	1-2	0.005*	0.003*
	1-3	1.000	0.500
	2-3	0.001*	0.001**
Cat_2	1-2	0.051	0.026*
	1-3	1.000	0.500
	2-3	0.044*	0.022*
Cat_3	1-2	0.161	0.081
	1-3	0.002*	0.001*
	2-3	0.624	0.312
Cat_4	1-2	0.930	0.465
	1-3	0.073	0.037*
	2-3	0.006*	0.003*

Bilateral p-value[a]: p-value provided by the Mann-Whitney U test, with the Bonferroni correction, for the bilateral median comparison test. Unilateral p-value unilateral[b]: p-value provided by the Mann-Whitney U test, with the Bonferroni correction, for the unilateral test whose alternative hypothesis is in accordance with the sample trend (See previous table where the averages and medians of each class are shown). Classes identified with numbers 1, 2, and 3 in Table A.8 correspond to years 10th, 11th, and 12th, respectively.

Questionnaire

Adapted from the survey originally known as the "Inventory of Teacher's Pedagogical & Scientific Beliefs (INPECIP)", by Porlán (1989).

Category 1: Image of Science

1   All scientific research begins with the systematic observation of the phenomenon under study.

2   Human knowledge is the fruit of the interaction between thought and reality.

3   The thinking of human beings is conditioned by subjective and emotional aspects.

4   The researcher's activity is conditioned by the intuitively suggested hypothesis about the problem under study.

5   In the observation of reality, it is impossible to avoid a certain degree of distortion introduced by the observer.

6   The effectiveness and objectivity of scientific work resides in following faithfully the ordered phases of the scientific method: observation, hypothesis, experiment, and construction of theories.

7   The scientific method fully ensures objectivity in the study of reality.

8   The scientific observer should not act under the influence of previous theories about the problem being studied.

9   Scientific knowledge is generated by our capacity as human beings to pose ourselves problems and imagine possible solutions for them.

10   The researcher tests the truth or falsehood of the working hypothesis through experiment.

11   The research process is directed by hypotheses.

12   Experiment is used in certain types of scientific research, but not in others.

13   Scientific theories, obtained at the end of a methodologically rigorous process, are a true reflection of reality.

14   Science has evolved historically by the accumulation of true theories.

Category 2: Personal didactic model

15   Didactics is today regarded as a scientific discipline.

16   Didactics has to define principles and norms to guide and orient educational practice.

17   The aim of Didactics is to describe and understand the teaching-learning processes that take place in the classroom.

18   The basic objective of Didactics is to define the techniques that are most appropriate for quality teaching.

19   A good textbook is an indispensable resource for science teaching.

20   The teacher must plan in full detail the tasks to be done in class by the teacher and the students to avoid improvisation.

21   Teachers have to make teaching tasks compatible with those of investigation into the processes that take place in their classes.

22 The students should intervene directly in the programming and evaluation of the activities in class.

23 Organized and hierarchized objectives should constitute the essential instrument guiding educational practice.

24 The school's organization must be based on flexible timetables and groupings.

25 Classroom work should be organized around the content.

26 Evaluation should be centered on measuring the level that the students have reached relative to the expected goals.

27 The teaching-learning processes that take place in every class are complex phenomena involving innumerable factors.

28 Didactics advances by means of processes of theoretical and practical research.

Category 3: Theory of learning

29 The starting point for scientific learning should be the students' spontaneous ideas.

30 Learning will be meaningful if the students are capable of applying it to different situations.

31 The students usually involuntarily distort the teacher's spoken explanations and the information in the textbooks.

32 The students have the capacity to form conceptions about the natural and social world spontaneously, by themselves.

33 Science learning takes place when the teacher explains a scientific concept with clarity and the student is paying attention.

34 The science learning that is essential for the students to assimilate in school is that which is related to the comprehension of concepts.

35 Learning is improved if the students relate the new content to their previous knowledge.

36 Scientific learning is meaningful when the students find a personal interest in what they are learning.

37 To learn a scientific concept, the student has to make a mental effort to memorize it.

38 The students show that they have learnt by correctly answering the questions that the teacher puts to them.

39 Conceptual errors should be corrected by explaining the correct interpretation as often as the student needs.

40 Students are more or less clever according to their innate abilities.

41 For learning to be meaningful, it is important that the students feel capable of learning by themselves.

42 Students' scientific learning must cover the data and concepts of science, and the processes of the scientific method (observation, hypotheses, etc.).

Category 4: Teaching methodology

43 The students learn scientific concepts correctly when they do practical activities.

44 Doing problems in class is the best alternative to the traditional master-pupil method of teaching

science.

45 To teach science, it is necessary to explain the topics without hurrying, so as to facilitate learning.

46 The library and the classroom bookshelf are indispensable resources for teaching science.

47 The teacher must replace the sequential list of topics to be covered by a list of central points of interest that cover the same content.

48 Contact with reality and laboratory work are indispensable for scientific learning.

49 The teacher constructs his or her own method of teaching science.

50 Science teaching methods based on student research do not stimulate the learning of specific content.

51 Science learning based on work with the textbook does not motivate the students.

52 In the science class it is advisable that the students should work in teams.

53 Most science textbooks do not facilitate comprehension and learning.

54 Science teaching based on spoken explanation of the topics encourages the students' rote learning of the content.

55 The correct way to learn science in primary education is by applying the scientific method in the classroom.

56 The teaching method is the form of presenting the scientific content.