E. Palacios-Bernuy, Y. Ocaña-Fernández, L. A. Valenzuela-Fernández. (2020). Effect of the API Program on the Scientific Inquiry of students in regular basic education in Lima. *International Journal of Early Childhood Special Education (INT-JECSE),* 12(1): 398-405
DOI: 10.9756/INT-JECSE/V12I1.201019

Received: 20.02.2020 Accepted: 07.05.2020

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Effect of the API Program on the Scientific Inquiry of students in regular basic education in Lima

Abstract

The need to train highly qualified professionals to serve the country is a pressing reality in the Peruvian case. The reason for such lack is the absence of adequate methodologies that promote the consolidation of investigative capacities from the school. For this reason, this research shows the benefits of applying a novel program (API) that enables students to develop research capabilities. A series of ten sessions with experimental and control groups was carried out in order to evaluate the effectiveness of the method to 46 high school students from an educational institution in Lima. For the estimates, two validated and reliable rubrics (Scientific inquiry and Level of development in the inquiry) were prepared (Cronbach's Alpha =, 799). The results were estimated by t-student (p <.005), therefore it is concluded that the developed method is effective in the development of scientific inquiry capacity.

Keywords: scientific inquiry, scientific method, critical thinking, scientific thinking.

Introduction

Today's society is affected by a diverse range of problems such as climate change, disease, malnutrition, poor nutrition, ecological devastation, global warming, among others, which is why it uses the products generated by science and technology to address the dilemmas that can be generated as liabilities of development and global progress (OAS, 2018).

Such development is only possible when society has individuals trained in areas related to science and/or technology development, who also possess critical thinking, curiosity, problem-solving skills and the ability to work in collaborative teams (Rodríguez, Chicaiza, Granda, Reinoso and Aguirre, 2017); but it must be recognized that in the realities of countries like Peru, there is a clear lack of a considerable number of specialized professionals with these characteristics and, in particular, those dedicated to the scientific field (OAS, 2018; Akbari, et al, 2013).

This situation has been the result of deficiencies in the educational field that precede the higher or university level and, on the other hand, a marked lack of investment in research (Scott, 2015).

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For a considerable time, schools have maintained an orthodox profile based on an education that transmits knowledge, with little motivation, most of the time decontextualized, segmented by memory, lacking incentives for reflection, participation and collective work (Rodríguez et al., 2017).

According to the above, UNICEF (2016) has mentioned that school activities aimed at memorization have not developed in students abilities of greater complexity such as problem solving, especially those mediated by research.

Based on the above, it should be noted that in secondary education there are factors that have not favored the development of school research, since they have only focused on activities such as memorization, mechanization of procedures, and identification of specific ideas without generating analyses and interpretations that require the use of complex thoughts.

It should be noted that students only follow instructions, do not present a position with solid arguments, nor do they develop critical thinking because many times the subjects treated in the classroom and the learning processes have no relation whatsoever to the events of daily life and its problems. These aspects slow down the development of research capacities and thus diminish the possibility of training cadres of specialized scientists or technicians capable of adequately applying scientific methodology in the resolution of the dilemmas of their context.

Although it is recognized that research can be a strategy that promotes scientific thought and inquiry, there were doubts about the possibility of doing research in the classrooms of primary and secondary students (Bejarano, 2015); however, there are studies that have shown encouraging results in this regard (Ruíz, Márquez, Badillo and Rodas; Barceló, Comas and Andrés, 2018; Hernández, Álvarez and Aranda, 2017).

A notable factor, which does not contribute to the development of scientific competencies through school research, is that on few occasions do teachers propose research projects to their students in which they make explicit use of guided and open inquiry; this is equivalent to the students themselves being the protagonists of the research process, developing each of the stages always under the supervision of the teacher (Franco, 2015).

Equivalent situations can be found in some countries that have a high school programme, in which research work is required at the end of this stage as the product of a higher level of investigation, in which adequate accompaniment is not provided and neither is it certified that the students, in previous stages, have learned to investigate (Ferrés, Marbá and Sanmartí, 2015).

That is why students who begin their research work show difficulties of rigor in their research work, since they carry out explanations and discussions of very brief analysis, without deepening or making reflections with respect to the work variables (Seferian, 2010).

On the other hand, taking as a reference framework the results on scientific competence according to the PISA test (Muñoz and Charro, 2018), particularly with regard to the design process and knowledge related to scientific research procedures (level two: basis of the performances required for today's society); that is, how to solve a researchable question, how to collect, analyse, interpret, represent and show data, the need for replication and maintaining constant conditions; it was found that students identify researchable questions, know basic procedures and can make interpretations, but with very simple designs. Various Latin American countries are below this level, among them Peru, where 27.9% of students managed to position themselves at this level, and only 2% reached the fourth level, and as one moves to higher levels, the percentage of Peruvian students decreases (Minedu, 2017; Niranjan, 2016).

This means that the Peruvian student has difficulty in recognizing a researchable question in a simple experience. This may be a consequence of the fact that in the classrooms no research or interpretation of graphs is done, for example.

Therefore, according to Abate, Bucari and Melgarejo (2019), societies in developing countries do not have scientific thinking, a situation that would lead to dilemmas when faced with problems that require scientific, technological and social issues.

In addition to all this, low scientific preparation is a strong promoter in discouraging students from learning science, distancing them from following scientific and technological professions, stressing that in the future this will generate a negative impact on innovation, progress and development of the country.

Theoretical Framework

Scientific inquiry

In science education, research considers inquiry as an object of learning, an aspect that transcends the role of imparting scientific knowledge, because it focuses on teaching the methods used in the scientific field (Romero, 2017). For his part, Ferrés (2017) believes that inquiry focuses on a series of processes such as generating questions, planning research, and analyzing what is already known in terms of new evidence, emulating the work of scientists, since it will allow students to have the ability to pose questions that guide possible research. Bogdan, Greca and Meneses (2017, p. 443), mentioned

that "during the inquiry process it is necessary for students to build models, clarify concepts and expand knowledge and skills applicable to other situations, in addition to learning some central elements about how to do science. This responds to a need to be able to consolidate the methodology of the sciences in the students using an orderly and systematized methodology, as required by the scientific field.

The scientific inquiry variable in this study was conceptually defined as a process by which knowledge is constructed and reconstructed autonomously, in which problems are identified, questions are formulated, specific knowledge is related to the problem, strategies are designed to collect data that provide answers to the problem and test or not the hypothesis, data and information are analyzed, weaknesses in the process are evaluated, improvements are proposed and the scope of the inquiry is reflected upon. And it is operationally defined with five dimensions: Problematizes situations to make inquiry, designs strategies to make inquiry, generates and records data and information, analyzes data and information and evaluates and communicates the process and result of its inquiry (Minedu, 2015, 2016, 2017).

This study took into account the dimensions of inquiry proposed by the Minedu (2015, 2016, 2017), which should be developed by the students. These dimensions are the following:

(1) Problematizes situations in order to carry out research; therefore, it is capable of describing situations by relating relevant aspects, and of asking questions or raising questions by relating variables in coherence to problems identified as a consequence of the observation of facts, phenomena and situations. It also involves the ability to formulate hypotheses, establishing causal relationships between possible variables.

(2) It designs strategies to make inquiries, when it is capable of proposing procedures that guide the verification of hypotheses; therefore, it has the capacity to handle, measure and control variables; select materials, tools and instruments to collect data; determine a control and experimental group if necessary; define the repetition of measurements in order to give reliability to the data; select information from reliable sources and elaborate the schedule of activities for the development of the research.

(3) Generates and records data and information, when it is able to record and systematize reliable data and represent them on graphs in order to facilitate their interpretation.

(4) Data and information analysis, when it is able to explain the relationships between variables and the trend of the results, to draw conclusions by contrasting the hypothesis, using reliable sources.

(5) Evaluates and communicates the process and result of its investigation, when it is able to communicate in different ways the new knowledge obtained in the investigation, founded on scientific bases and based on the interpretation of data and results. Also when it is able to recognize the causes of possible limitations that influence the reliability of the results of the investigation and propose improvements or other investigations.

Methodology

Type of study

The method that supports the research was the hypothetical-deductive one, with a quasi-experimental design, within the framework of the quantitative approach, of the applied type, of explanatory level.

Population

The population was census-type, consisting of 46 students in the fourth year of secondary education in an Educational Institution (IE) in Lima, 23 boys and 23 girls. The choice of the mentioned students had ages that fluctuated between 15 and 16 years old.

Their choice was based on their accessibility, as well as being at a higher level of abstraction for the cognitive demands required by the application of the API program, in addition to possessing prior knowledge, both conceptual and procedural, of the previous grades and also showing attitudes and interest in new learning.

Procedure

The API program was developed to be applied in a learning unit (ten weeks), distributed in ten sessions of two pedagogical hours each. Each session has particular strategies and resources according to the objectives pursued and the characteristics of the students, and at the end of each class there are products that show the level of achievement achieved.

Likewise, individual and collaborative team work was developed, which is constantly being evaluated and given feedback through spaces for reflection that, thanks to the contributions, promote improvements and consolidate learning.

For the collection of data the technique of observation. In the present study, questionnaires or tests were used for purposes that require thematic knowledge of science and the capacity for scientific inquiry.

These questionnaires (pre-test and post-test) have open-ended questions to collect more information (Hernández and Mendoza, 2018) regarding the processes of inquiry that the student carries out when answering the questions, these processes are related to the indicators proposed for each ability.

The validation was done by expert judgement and the reliability by Alfa de Cronbach (, 799).

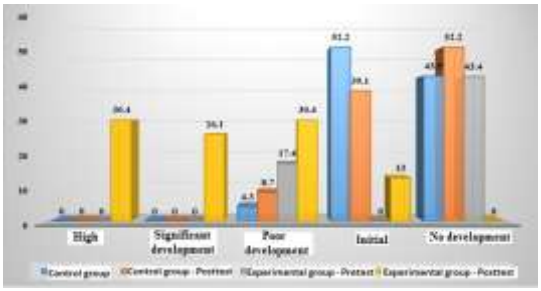
For the estimation in each developed session, the corresponding heading was applied which estimated five levels: 'Highly developed', 'Appreciable development', 'Little developed', 'Beginning of development' and 'No development'; which was adapted based on the NPTA1 instrument (Ferrés, Marbá and Sanmartí, 2015), due to the reformulation of the descriptions in function of the indicators proposed by the Minedu.

After the application of the heading, the instrument called 'Description of Levels' was used, which was adapted from the NCI of Ferrés et al. (2015). This contains an ordinal scale, which indicates at what level the 'development of investigative skills' is, in general terms, consisting of five levels: 'Highly developed', 'Appreciable development', 'Poor development', 'Beginning of development' and 'No development'.

As the present research is of an explanatory type, the effect of the independent variable API Program on the dependent variable 'Scientific inquiry' was studied, for which the Student t data analysis method was used to compare the control and experimental groups in their means and distributions, using IBM's SPSS version 24 software.

Results

The levels of scientific inquiry that the students in the experimental group have reached after the program intervention, data processed after the collection in the pre-test and post-test. Data from the control group is also observed.



Graph 1.
Levels of Scientific Inquiry in pre and post-test of the control and experimental group

When comparing the results of the pre-test and post-test between the control group and the experimental group made up of fourth-year students from an IE in Lima, it was observed that the levels of development of the 'scientific inquiry' competence in the pre-test in both groups are similar. After processing the data it was obtained that in the control group it was manifested in the following way: 4.3% of students show 'Little development' of the mentioned competence, 52.2% of students were in the 'Beginning of the development'; while in 43.5% of the students it did not show the smaller indication of development of the mentioned competence.

Similarly, in the pre-test for the experimental group it was observed that 17.4% of the students showed 'Little development' of the competence, 39.1% were at the 'Beginning of development' and 52.2% did not show any evidence of the development of the competence.

On the other hand, in the post-test the control group (which has continued with the ordinary learning system) shows that 8.7% of students showed 'Little development' of the competence 'Scientific inquiry', 39.1% were at the 'Beginning of development' and 52.2% showed no evidence of the development of the competence.

On the other hand, after implementing the intervention with the API Program in the experimental group, the percentage of the distribution of students according to the level of development of the mentioned competency was mobilized in an ascending manner; the group of students in which there was no development of the competency disappeared completely; rather, all of them were located in some level of development; only 13% of students were in the 'Beginning of the development'.

The 30.4% were identified in the level 'Little development' and more than half of the students showed the scope of development of the mentioned competence, highlighting that 26.1% presented 'Appreciable development' and it is also highlighted that 30.4% of students were located in the 'Highest' level of development of the competence, which meant that they have achieved in an excellent way the understanding and management of the investigative processes of the competence 'Scientific investigation'.

Discussion

From the results obtained in the present study, it was determined that the API Program improves the development of the 'scientific inquiry' competence and of all their abilities to do inquiry of the students of an IE in Lima. These findings are related to what was stated by Franco (2015), whose study shows that adolescent students can correctly develop the abilities of scientific inquiry. Similarly, Manco (2019), used strategies in the methodology of learning for research, finding a remarkable improvement in inquiry in high school students. Likewise, Rojas (2018), in his research on scientific inquiry competence in fourth-year secondary school students, managed to improve the development of such competence and the inquiry skills

proposed by the Minedu. Finally, Quispe (2015), states that the investigative competence is notoriously influenced in its development when methodological investigative procedures are applied.

Cabe resaltar que, al comparar capacidad por capacidad, existen coincidencias y diferencias. Por ejemplo: en el caso de 'problematiza situaciones' se obtuvo que el 69,6% de estudiantes se ubica en un nivel alto. Cabe acotar que no todos los estudiantes logran la eficacia en esta capacidad, ello implica que no todos los estudiantes consideran criterios para plantear preguntas investigables e hipótesis, debido a que no se realizan prácticas continuas.

De la misma forma, para la capacidad 'diseña estrategias', demuestra que los estudiantes se encuentran en proceso de logro; lo cual puede deberse a que los procesos de indagación científica se presentan de una forma más compleja, además de considerar que los estudiantes tienen dificultades para proponer procedimientos a llevarse a cabo para las mediciones, identificar las variables a controlar, plantear acciones a realizar; por lo cual los estudiantes requieren una mayor formación al respecto a fin de afrontar con éxito tales dificultades.

En lo que respecta a la dimensión 'genera y registra datos', la distribución de estudiantes en los diferentes niveles coinciden en los dos grupos analizados, ubicándose un promedio del 30% en el nivel alto; lo que se traduce en que la mayoría de los estudiantes todavía no alcanzan consolidarse en el nivel más alto toda vez que hay muchos criterios a tener en cuenta como la cantidad de datos suficientes, el tratamiento matemático adecuado, la información clara y completa de los datos y la elección de las gráficas adecuados para representar la data.

En cuanto a los resultados de la dimensión 'Analiza información', se deduce que mientras más compleja sea la capacidad que deban afrontar los estudiantes, presentarán mayores dificultades; este aspecto se debe a que dicha capacidad exige operaciones cognitivas complejas tales como contrastar, integrar y teorizar información para dar respuesta al problema.

Finalmente, frente la capacidad 'evalúa y comunica el proceso y resultado de su indagación', los resultados son bajos para ambos grupos consultados, ello debido a que se exige que el estudiante debe sintetizar y sistematizar la investigación, y además de ello aportar su reflexión y crítica al evaluar las deficiencias de su trabajo a fin de plantear mejoras, lo que se entiende como niveles de pensamiento complejo que, en tan poco tiempo, no se puede consolidar. En síntesis, los hallazgos permiten afirmar que cuanto más se complejiza las capacidades de la 'indagación científica', más dificultades se generan frente al logro posible de los estudiantes; por ello deberá considerar que se tiene que fomentar en las sesiones de clase muchas oportunidades de hacer investigación en donde el maestro acompañe permanentemente aclarando dudas y retroalimentando los aprendizajes.

Por otro lado, al comparar los resultados de la presente investigación con las estimaciones hechas por Gonzáles y Crujeiras (2016), se estimaron que hay avances en los desempeños de algunos procesos indagatorios, concentrándose la mayor dificultad en el diseño experimental o metodológico; de ello se puede inferir que dicha capacidad por ser más compleja, muestra mayor dificultad para ser lograda por los estudiantes.

Por otro lado, el presente estudio difiere con lo estimado por Crujeiras y Cambeiro (2017), en cuanto a los resultados en cuanto al planteamiento de hipótesis y definición de variables, ya que en el presente estudio la mayoría de los estudiantes logra una adecuada identificación del problema, planteamiento de la pregunta, así como la hipótesis y variables. Dicho avance puede adjudicarse al aprendizaje de los primeros grados que ha formado ciertas habilidades al respecto.

Conclusiones

De los resultados descriptivos se puede concluir que, en líneas generales, el efecto del programa API en el desarrollo de la competencia 'Indagación científica' y sus respectivas capacidades de los estudiantes del cuarto grado de secundaria de una IE de Lima han sido eficaces en el aprendizaje de la ciencia en la modalidad indagación guiada. De las estimaciones de los resultados presentados en el presente trabajo se puede afirmar que, es relevante la aplicación del programa en la mejora del desarrollo de las habilidades de indagación científica, pero al mismo tiempo se reconoce la necesidad de suministrarlo continuamente y desde los primeros grados o niveles con la finalidad de poder consolidar los aprendizaje en el estudiante y consecuentemente a la postre pueda aplicar sus capacidades investigativas cuando acceda a la educación universitaria.

Se plantea que es tarea del docente generar continuamente situaciones para profundizar paso a paso la elaboración de diseños metodológicos de investigación científica teniendo en cuenta la hipótesis a probar; el manejo, medición y control de variables; las réplicas; el control, y los recursos y procedimientos lógicos a realizar. También se reconoce que, las actividades de investigación favorecen la puesta en práctica de contenidos temáticos para la resolución de un problema. De esta forma el estudiante irá consolidando la

plataforma cognitiva que necesita para investigar.

It should be noted that, when comparing capacity by capacity, there are both coincidences and differences. For example: in the case of 'problematizes situations' we obtained that 69.6% of students are at a high level. It should be noted that not all students achieve effectiveness in this capacity, which implies that not all students consider criteria to pose researchable questions and hypotheses, due to the fact that they do not carry out continuous practices.

This may be due to the fact that the processes of scientific inquiry are presented in a more complex way, and that students have difficulties in proposing procedures to be carried out for measurements, identifying variables to be controlled, and proposing actions to be taken.

This means that the majority of students still do not reach the highest level, since there are many criteria to be taken into account, such as sufficient data, appropriate mathematical treatment, clear and complete information on the data, and the choice of appropriate graphs to represent the data.

As for the results of the 'Analyze Information' dimension, it can be deduced that the more complex the capacity that students must face, the greater the difficulties; this aspect is due to the fact that this capacity requires complex cognitive operations such as contrasting, integrating and theorizing information in order to respond to the problem.

Finally, when faced with the ability to 'evaluate and communicate the process and result of their research', the results are low for both groups consulted, due to the fact that the student must synthesize and systematize the research, and in addition, contribute his/her reflection and criticism when evaluating the deficiencies of his/her work in order to propose improvements, which is understood as levels of complex thought that, in such a short time, cannot be consolidated. In summary, the findings allow us to affirm that the more complex the capacities of 'scientific inquiry', the more difficulties are generated in terms of the possible achievement of students; for this reason, teachers should consider that many opportunities to carry out research should be encouraged in class sessions, in which they should permanently accompany students, clarifying doubts and providing them with feedback on their learning.

On the other hand, when comparing the results of the present research with the estimates made by Gonzáles and Crujeiras (2016), it was estimated that there are advances in the performance of some investigative processes, with the greatest difficulty being concentrated in the experimental or methodological design.

On the other hand, the present study differs from the estimates of Crujeiras and Cambeiro (2017), in terms of the results regarding the hypothesis and definition of variables, since in the present study the majority of students achieve an adequate identification of the problem, the question, as well as the hypothesis and variables. This progress can be attributed to the learning of the first grades that has formed certain skills in this respect.

Conclusions

From the descriptive results, it can be concluded that, in general, the effect of the API programme on the development of the 'scientific inquiry' competence and their respective capacities of the fourth grade students of an IE in Lima have been effective in the learning of science in the guided inquiry mode. From the estimations of the results presented in this work, it can be stated that the application of the program in the improvement of the development of scientific inquiry skills is relevant, but at the same time the need to provide it continuously and from the first grades or levels is recognized with the purpose of being able to consolidate the learning in the student and consequently at the end he can apply his research skills when he enters the university education.

It is the task of teachers to continuously generate situations in order to deepen, step by step, the elaboration of methodological designs for scientific research, taking into account the hypothesis to be tested, the handling, measurement and control of variables, the replications, the control, and the logical resources and procedures to be carried out. It is also recognized that the research activities favor the implementation of counts

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