Journal of Philosophical Investigations
Print ISSN: 2251-7960 Online ISSN: 2423-4419
Homepage: https://philosophy.tabrizu.ac.ir

The Effects of Critical Rationalism on the Development of Critical Thinking Abilities; a case study with senior high school students in Manizales, Colombia

Carlos-Emilio García-Duque[1] ✉ | **Héctor-Fernando Giraldo-Bedoya**[2]

1 Professor of Philosophy at the Department of Philosophy, Universidad de Caldas, Colombia. Professor of Epistemology, Universidad de Manizales, Colombia. E-mail: carlos.garcia_d@ucaldas.edu.co
2 Professor of philosophy at the Department of Philosophy, Universidad de Caldas, Colombia. E-mail: hectorfgiraldo@gmail.com

Article Info

Article type:
Research Article

Article history:
Received 25 January 2023
Received in revised form 17 April 2023
Accepted 19 May 2023
Published online 18 June 2023

Keywords:
Critical Rationalism, Critical Thinking, Developing Reasoning Abilities, Popper

ABSTRACT

Fostering critical thinking among senior high school students in Colombia has been an unfulfilled goal. This undesirable situation has multiple causes: "critical thinking" has become a mere slogan and its meaning and scope have not been clearly specified despite being widely used in the different levels of the education system. Furthermore, the strategies designed to teach critical thinking lack creativity, reinforce rote learning and the sheer repetition of logic rules besides misallocating the goal of reasoning and argumentation by focusing only on rhetorical persuasion. Textbooks and core literature in critical thinking suggest that a critical thinker is someone who always has plenty of arguments to defend her beliefs besides being ready to address even destructive criticism. By contrast, critical rationalism emphasizes the importance of a humble approach, acknowledges error, and portrays a critical thinker as someone who is ready to test her most beloved theories against experience and to reject them in the light of the facts that contradict her beliefs and certainties. We consider that a pedagogical approach enriched with fallibilism might be central for a better education and endorse these views with the results of a case study conducted in Manizales, Colombia, which shows that teaching the basics of logic and argumentation by using the central tenets of critical rationalism fosters critical thinking among senior high school students.

Cite this article García-Duque, C. E. & Giraldo-Bedoya, H. F. **(**2023). The Effects of Critical Rationalism on the Development of Critical Thinking Abilities; a case study with senior high school students in Manizales, Colombia. *Journal of Philosophical Investigations*, 17(42), 40-54. http//doi.org/10.22034/jpiut.2000.16570

© The Author(s).
Publisher: University of Tabriz.
http//doi.org/10.22034/jpiut.2000.16570

1. Introduction

The third decade of the 21st century put serious challenges to humankind. The pandemic caused by COVID-19 made clear not only that our health and lifestyle were in danger but also our democracies (Pinker, 2021). Fake news, conspiracy theories and magic answers became more prevalent and the general result was confusion. How to distinguish truth from falsity in a world flooded by irrelevant information? The answer is not easy (Harari, 2018). After science enabled us to develop vaccines to protect us against the virus of COVID-19, we faced a new threat due to the Russia-Ukraine war. Could such an event show conclusively that humankind is guided by irrationality? Many analyses of the world's situation suggest a positive answer to this.

However, there are many other facts that support another way to understand this situation. Recognizing that there is still a lot of room for improvement, humankind has achieved remarkable milestones such as space travel, the discovery and understanding of natural laws, the increasing ability to change and modify nature, the application of the methods of modern science to recent and widespread technologies (such as internet and artificial intelligence) not to mention the increase in our life expectancy as well as the improvement of the conditions of habitability. All these achievements seem to suggest that we have surpassed, in an extraordinary way, human instinct and have been able to use extensively and systematically our rationality. But there are many reasons that uphold the idea that our very rationality is endangered.

Facing this worrisome situation does not have to lead to desperation. We have some tools at hand that, if employed in a resourceful way, can help us to overcome or at least to counteract the menace. And this is a pressing purpose. Popper bequeathed us Critical Rationalism, a powerful tool that could be potentially useful in education, in particular, to develop higher order abilities such as critical thinking (Giraldo & García, 2019), though its meaning and scope need some clarification. Let us start by casting some light over the locution "critical rationalism".

We suggest that critical rationalism is the result of the rational and sincere effort to search for evidence that can overthrow our more cherished ideas and beliefs, instead of searching for supporting arguments or confirming evidence. For this reason, we think that the methodology of critical rationalism, besides implying a defense of reason puts it in its right place, since it dictates that a critical thinker is not someone who strives to protect her ideas with clever arguments and tries to persuade others about their alleged truth, as customary, but someone who evaluates the consequences of her ideas and is ready to renounce them if they do not stand the test of experience or do not resist rational criticism. To sum up, it is important to emphasize that critical rationalism focuses in the use of negative criticism; hence the warning of not confusing *necessitas consequentiae* with *necessitas consequentis*. (Miller, 2005).

If we subscribe the main tenets of critical rationalism, we soon realize that the main purpose of argument is not justificatory –unlike what is found in literature (e.g., Fisher, 1988: 16). From the point of view of critical rationalism, it is not possible to advance reasons to support, prove or demonstrate. Instead, we can rationally criticize, understanding such criticism as an activity that

does not aim to logically support conclusions but that seeks to get closer to the truth by the progressive and systematic use of what has been called a negative method. Critical rationalism is pertinent —and essential— in education since by the method of conjectures followed by refutations, we might identify error and introduce corrections to overcome what has been called *God's complex* (Harford, 2011) and humbly recognize human shortcomings, especially our fallibility.[1]

2. Problem

Literature devoted to studying critical thinking and highlighting its importance for higher education is abundant (Dunne, 2015; Ennis, 1987; Facione, 1998; Paul, 2012; Siegel, 1988). There is no agreement on what critical thinking amounts to, but there are several definitions that can be traced back from ancient times to our own age. In classical Greece, Socrates and Aristotle are two main figures.[2] One of the most important contentions of the former says that a life unexamined is not worth living, hence the Socratic invitation: "Know thyself", while the latter was a pioneer in the systematization of Logic as a tool for scientific research; in fact, some thinkers have defined it as the science that gives the rules and principles or valid inference.

The Middle Age has also critical thinkers: John Duns Scotus, William of Ockham and Saint Thomas Aquinas can be considered as such. The first of them held that reason should not be subjected to any censorship by authority, but, contrariwise, reason should control authority. Ockham is an example of bravery since he was harassed because of his efforts to find out whether the Papacy applied its doctrine of poverty to itself. He also considered Pope John XXII as a heresiarch. Ockham is well known for his innovative methodological principle called nowadays "the principle of parsimony", that clearly encompasses a basic element of critical thinking: when explaining something we should recur to the fewest number of possible causes, factors or variables. Saint Thomas Aquinas developed an extraordinary argumentative technique in his *Summa Theologicae* introducing the anticipation of objections to his views, so that he could analyze and respond, in a systematic way, such objections.

In the Renaissance and the Modern times one can find several important critical thinkers. Cultural and intellectual renowned movements such as the Enlightenment, the Scientific Revolution and the Protestant Reformation were a result of their ideas. With the former, ancient Greek culture in all its guises (art, literature and philosophy) reappeared through an unprecedented influence on western thought. The Reformation of Luther and Calvin in the early 16th century broke the unity of the Catholic Church because the main motivation was the

[1] The tradition of critical rationalism, understood as the way to increase knowledge, implies that all our knowledge is provisional, conjectural and hypothetical. These ideas should not be absent from the school setting if we consider Popper's complaint: "[The student], in my view, has been taught badly. I believe, and so do many others, that all teaching on the University level (and if possible, below) should be training and encouragement in critical thinking" (Popper, 1970: 52-53).

[2] Plato would need a more detailed analysis since he is a defender of closed societies (as Popper shows in *The Open Society and Its Enemies*), and the idea of a critical thinker that does not contribute to the consolidation of open societies is troublesome. In contrast to Plato's view, some Pre-Socratics, among them the Ionian School, deserve special recognition for their critical attitude.

individual salvation of the soul through faith with no mediation of the ecclesiastical authority. (Stevenson & Haberman, 2004). The 17th century scientific revolution brought substantial changes since Copernican astronomy moved the Earth away from the center of the universe changing man's image of himself and of the world. The Enlightenment, which occurred in the 18th century took different paths in England and France, but gave birth to the hope that scientific method was useful to gain knowledge about the natural world, contributed to the knowledge of human nature and improved our living conditions. In short, Renaissance scholars were interested in knowing, understanding and explaining phenomena by using rational criticism. No matter how short this summary is, it would not be complete without mentioning the influence of the Cartesian philosophy. Let us recall that Descartes's *Rules for the Direction of the Mind*, albeit incomplete, contains an excellent introduction to the method of critical thinking, since they are based on the principle of hyperbolic doubt and recommend that one must question and check very item of thought.

We can find more developed and important studies on critical thinking in the 20th century as they appear in the works by Dewey (1933), *How We Think*; Ennis (1987), *"A Taxonomy of Critical Thinking Dispositions and Abilities"*; Fisher (1988), *The Logic of Real Arguments*; Facione (1998), *Critical Thinking: What It is and Why it Counts*; Lipman (1988), *Philosophy Goes to School*; Siegel, *Educating Reason: Rationality, Critical Thinking, and Education* (1988) and his paper "The Rationality of Science, Critical Thinking, and Science Education" (1989); Schlecht (1989), "Critical thinking courses: their value and limits"; Toulmin (2003), *The Uses of Argument*, and many other authors who can be easily located in the literature.

However, there is a salient and common characteristic in almost every source consulted: most of these scholars suggest in a rather direct way, that Socrates is a good model of what it means to be a critical thinker. This does not imply that Socratic criticism is determinant or decisive in handbooks for teaching critical thinking, since they contain very general descriptions and recommendations while claiming that the aim of argumentation is a combination of justification and persuasion, goals that entail authority and seem to favor dogmatism. For this reason, we prefer a view more entrenched in Popperian critical rationalism.

Popper's method promotes, besides critical rationalism, tolerance as well as the respect for difference. However, when one finds the hope for a better world in open societies, one has to fight with neither remorse nor tolerance against the defenders and perpetuators of closed and dogmatic societies —what amounts to an inevitable paradox[1]— especially in times of confusion

[1] We must take into account the so-called *paradox of tolerance* as stated by Popper (1945): "Unlimited tolerance must lead to the disappearance of tolerance. If we extend unlimited tolerance even to those who are intolerant, if we are not prepared to defend a tolerant society against the onslaught of the intolerant, then the tolerant will be destroyed, and tolerance with them. —In this formulation, I do not imply, for instance, that we should always suppress the utterance of intolerant philosophies; as long as we can counter them by rational argument and keep them in check by public opinion, suppression would certainly be most unwise. But we should claim the *right* to suppress them, if necessary, even by force; for it may easily turn out that they are not prepared to meet us on the level of rational argument, but begin by denouncing all argument; they may forbid their followers to listen to rational argument, because it is deceptive, and teach them to answer arguments by the use of their fists or pistols. We should therefore claim, in the name of tolerance, the right not to tolerate the intolerant. We should claim that any

and obscurantism disguised as nationalism and democracy. The promoters of closed societies seem not to be ready to recognize and correct mistakes, they tend to consider themselves as infallible and eagerly offer justifications even to the unacceptable. In fact, they are so stubborn with justifying their acts and decisions that they frequently go into the terrain of comedy. Politics in Latin America (as well as in Colombia) provide plenty of examples. To mention just one, consider the Colombian´s government response to the criticisms for the continuous killing of social leaders during the years following the peace agreements signed in 2016. Instead of adopting effective measures to protect the lives of the social leaders, the government has refused to acknowledge the gravity of the situation and has attempted to minimize it by calling the massacres with names like "collective killings" as if using euphemisms had any effect on the problem.

We are not disputing the idea that Socrates and his method are a good model of rational criticism. As a matter of fact, Socrates' philosophy and Socrates' attitude, as well as that of the first natural philosophers, are cornerstones of our project and we concede that what is called in the literature as "Popperian critical rationalism" has to be traced back to the pre-Socratic philosophers,[1] mainly the Ionians who characterized themselves by openly discussing their views, unlike the Pythagoreans, whose teachers devoted themselves to train a small and select group of people and to keep the Pythagorean doctrine pure and unchanged. We find an example of this in the criticisms raised by Anaximander to Thales and this suggests, according to Popper, that good teachers not only are quite tolerant with criticism but also that they stimulate it, since it is unlikely that a pupil taught within the boundaries of dogmatism would dare to criticize her teacher. If what we have learned about Hippasus of Metapontum is true, exemplifies the intolerance characteristic of some dogmatic and esoteric trends. Allegedly, he was expelled from the Pythagorean School because he discovered irrational numbers.

> […] the historical fact that the Ionian school was the first in which pupils criticized their masters, in one generation after the other. There can be little doubt that the Greek tradition of philosophical criticism had its main source in Ionia. (Popper, 1963: Chapter 5, section XI)

We subscribe to Popper's claim that trial and error, conjectures and refutations, is the only method to solve problems and apply this central element of critical rationalism to our project.[2] Our hypothesis is that the best way of promoting higher-order thinking abilities, including critical

movement preaching intolerance places itself outside the law and we should consider incitement to intolerance and persecution as criminal, in the same way as we should consider incitement to murder, or to kidnapping, or to the revival of the slave trade, as criminal" (Chapter 7, Note 4).

[1] Popper (1998) defends this thesis in the first essay of his book *The World of Parmenides. Essays on the Pre-Socratic Enlightenment*; specifically in section XI.

[2] The use of Popper's philosophy to do research in education has a long tradition that goes back to the seventies (McNamara, 1978). Though Popper did not publish any full work on education, he shared here and there his own experiences as a school teacher as well as a pupil. His opinions on this matter have become hallmarks in current literature

thinking, implies not only assuming the central principles of Popper's rationalism, but also making sure that the resources of logic and argumentation are used in the continuous process of generation and refinement of ideas, formation of views, and argued discussion. Based on a claim by García (2005), in this work we tried to test the following two theses: familiarity with basic logical tools is a necessary condition to develop critical thinking abilities in such a way that they improve the students' capabilities to make correct inferences[1]; critical thinking becomes empowered when we consider seriously views that are quite different to our preferred view and when the arguers engage in argumentative discussion to test their views severely.

3. Method

A crucial question in the field of education has to do with the widely diagnosed difficulties of senior high school students to understand the actual world, make some progress in their knowledge about it, and use reasoning abilities in a functional way. A particular case emerges when considering controversial issues — such as those in the field of moral philosophy— or some other matters that are important for society. The beliefs of senior high school students barely go further than uninformed or hasty opinions,[2] they have serious difficulties arguing in an articulated way for their views and very often they refuse to take part in any exercise that requires from them a more fine-grained work involving the principled defense of their points of view. They seem to be afraid of error without realizing that one could learn from a clearly identified mistake. It is common to see a great deal of frustration coming from their inability to locate the sources of their confusion and errors.

This project intends to test the controversial thesis that some familiarity with the basic tools of logic can stimulate the development of argumentative and critical thinking abilities, besides enabling the students to participate in argued debates and help them to understand the fallible nature of our reason and to admit that, as beings prone to blunder, by carefully identifying errors (through criticism) and making the appropriate changes, one can make important progress towards knowledge. A specific presupposition of this project is to use a rather different approach to the task of gaining familiarity with the tools of logic. Instead of teaching them in the traditional way or asking the students to memorize the definitions required and solve exercises we tried to use an intuitive approach consisting in several discussion exercises in the classroom to stimulate argument and criticism involving some logical key concepts. To test this approach, we ran a quasi-experiment as described in the classification by Campbell and Stanley[3] (1966) with two

[1] This thesis is not peculiar to Critical Rationalism. However, we think it can be assumed here without any special difficulty.

[2] The word "opinion" is used here in the sense intended by Pre-Socratic philosophers when they contrasted its meaning with knowledge (or *episteme*); i.e., *dox*a as synonymous of "superficial hasty view about something, not founded on reason". In the education setting we can form (and help our students to form) views that are the result of argumentative and deliberative processes, which, examined with the method of critical rationalism can be progressively refined to become the best views one can obtain. It should be clear that we are criticizing here only the type of opinion that cannot withstand critical analysis.

[3] They discuss three types of experimental stages: I) pre-experiments, ii) "pure" experiments, and iii) quasi-experiments. They also define the locution "intact group" as an already-formed group (e.g., church groups, political organisations, or classrooms

intact groups of students. This means that they were neither randomly assigned to each group nor paired with each other. Instead, before the test, they had been assigned to different groups by the system of class enrolling used in the school where this work was conducted. Leaving aside this condition, we can say that our design can be extended to pre-experiments and "experiments proper". First, because between the years 2016 and 2017, long before conducting this study, we applied some tests to asses the hypothesis that familiarity with logic would produce better levels of reasoning and because we tried to control some independent variables —the teaching and the application of basic tools of informal logic and traditional logic—, we measured the dependent variables and did the corresponding comparison between two different groups (which could be considered as experimental and control[1]). In addition, we applied some instruments to collect and analyze information: a pre-test (or diagnostic test), and two post-tests (mid test and final test).

During the year 2018, we worked with two groups of tenth-graders[2] of the *Instituto Universitario de Caldas.* As already mentioned, we chose, randomly, a group to be the "control group" (hereafter, CG) and the other to be the "experimental group" (hereafter, EG)[3]. The experimental study lasted for a school year (40 weeks divided into four ten-week periods). After applying the diagnostic test in late February, we asked the students of the EG to read *Harry Stottlemier's Discovery* (Lipman, 1974), a novel that is part of the core *curriculum* of the program Philosophy for Children, aimed at developing critical, reflexive and cooperative thinking by changing the classroom into a *community of inquiry* (Lipman *et al*., 1980). Such strategy promotes debate and takes advantage of the natural amazement and curiosity among students as well as their capacity to pose questions and think for themselves.

In the second stage the students of the EG participated in discussions on several issues after studying and considering some basic concepts of classical logic taken from *Introduction to Logic* (Copi, *et al*. 2013). We chose this textbook due to its common use with freshmen students in college and because it stimulates some abilities like analyzing, synthesizing, recognizing and producing arguments which are congenial to our overall project.

The CG covered the same material from Copi *et al*., by the traditional methodology including studying some inferences and solving exercises. In the traditional approach, sheer memorization of definitions and rules becomes the main component of instruction. As is well known, the students are asked to memorize rules, cases and exceptions with little attention paid to conceptual comprehension.

To test our hypotheses and collect data about the students' performance during this study, we applied three instruments that included three types of questions ordered in an increasing degree of

of students) that is entirely assigned to a specific treatment. In these cases, no selection procedure is used, but the entire group is used to represent some larger population.

[1] The "experimental" group was composed of 24 students and the control group was composed of 22 students. The whole number (46 students) is the number of people that participated in this study during the whole school year.

[2] Unlike the US or Europe high school education in Colombia finishes in the 11th grade.

[3] After finishing the quasi-experiment, we did remedial work with the CG to make sure they attained the same level of ability as their peers in the EG.

difficulty. The questions, taken from a larger pool, changed from test to test but required from the test takers the same general abilities. The first type of questions involved the theory of immediate inferences, the second type of questions involved the basic mediate inferences[1] and the third type involved both immediate and mediate inferences in addition to some basic reasoning rules of first order logic (Annex 1). The first research tool is an initial conditions test that evaluates the students' logical intuitions and their ability to make the right inferences (this test was applied in late February to both groups). The second test (applied in late May to both groups) was designed to measure the degree of progress of the students in the EG after reading the work of Lipman and engaging in argumentative discussion sessions while their peers in the CG were taught the basic concepts of logic by using the traditional approach, and the third test (applied in Late September to both groups) measures the student's degree of progress after finishing all the reading and discussion assignments with the explained differences between the CG and the EG. The results of the last test provide some information that could be interpreted as a corroboration of the positive effects of the treatment administered.

4. Results and discussion

First research tool: diagnostic test

This instrument aimed to determine and compare the initial state as well as the ability of the participants to make inferences. The bars of tendency of the results show that groups G1 and G2 are equivalent with no significant statistical differences (measured by taking into account the means and standard deviations of the test results) that could endanger the internal validity of the quasi-experiment (figure 1).[2]

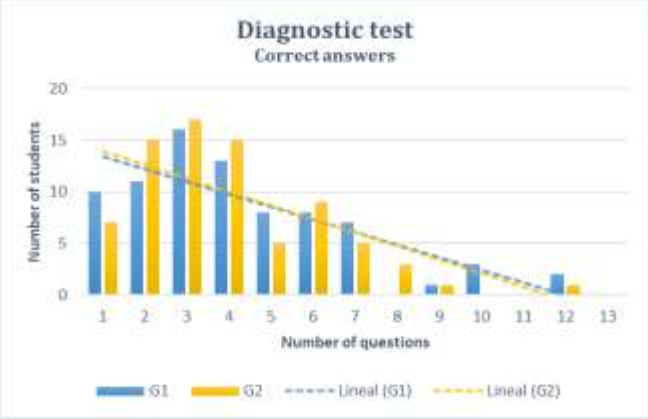

Figure 1. Correct answers in diagnostic test of G1 and G2

[1] One-premised inferences are called "immediate inferences" because there is nothing that "mediates" between the premise and the conclusion (paradigmatic examples are studied in the traditional square of opposition). Mediate inferences (like syllogisms) are two-premised inferences. It is supposed that the second (or minor) premise mediates between the first (or major) premise and the conclusion.

[2] Since at this moment we had not decided yet which group was to be treated as experimental and which as control, we called them by using the neutral labels G1 and G2. After the decision was made and as the study progressed G1 became the Control Group (CG) and G2 the Experimental Group (EG).

Resource: own production.

The test questions require appropriate reading comprehension to make correct inferences as well as the intuitive ability to determine the logical scope of quantifiers. At this moment, the participants are not familiarized with the basic concepts of the theory of immediate inferences; they lack the required conditions to determine the scope of the quantifiers based only in the questions' content. However, they still could answer correctly and offer acceptable reasons to support their answers if they had the appropriate logical intuitions. Obtaining correct answers can be accounted for in two ways. Firstly, the students may just have guessed the right answers yet they lack a high reading level or cannot produce satisfactory reasons. Secondly, students who are good readers and have the appropriate logic intuitions may be able to pick up the right answer and to offer acceptable reasons, which are neither formulated in a technical way nor conform to the standard definitions.

Second research tool: intermediate test

After completing the first stage of the quasi-experimental treatment, we applied the second research tool to measure the progress of the participants. In order not to affect the validity of the comparison, the design of this test was equivalent to the design of the first one. Global scores of the EG showed an indisputable improvement compared to the scores the students got in the diagnostic test and to the scores of the intermediate test of the students in the CG. Similarly, the scores of the intermediate test in the CG improved compared to the scores in the diagnostic test, but the improvement was lower than the one achieved by the EG. This suggests that having read the work by Lipman and having engaged in the discussion exercises enabled the students to improve their scores in a significant way.

In what follows, we analyze the results of the second test. We start by comparing the scores with what each group got in the diagnostic test. After doing this, we contrast the scores of each group in the intermediate test.

EG results

In figure 3, the grey bar shows the results of the first test, while the blue bar displays the results of the second test. The horizontal dotted lines allow us to present the tendencies of the correct results in both tests; while the scores in the diagnostic test fall sharply after the first question, this decrease occurs in the intermediate test after the eighth question.

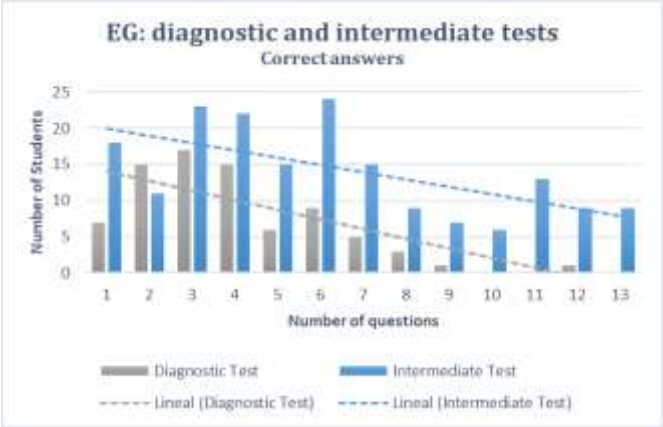

Figure 2. Correct answers in the diagnostic and intermediate test of EG
Resource: own production.

By comparing the tendency lines, we can notice that there is an important difference: the tendency of the second test is well above of the tendency of the diagnostic test. Indeed, the results of the intermediate test, except for question 2, are better. Though the students missed questions 10, 11, and 13 in the diagnostic test the situation changed completely for the second test in which we registered several correct answers for these items.

CG results

Figure 3 depicts the results of the CG for both tests. We can see that the overall results for both the CG and the EG improved compared to the diagnostic test but the scores of the EG are far better than the scores of the CG —a result that corroborates our conjecture.

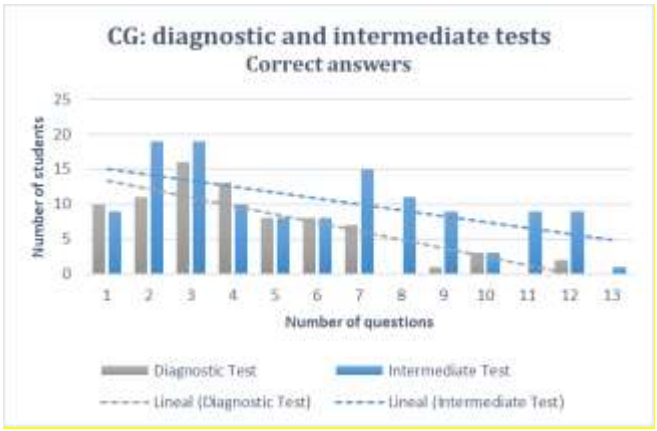

Figure 3. Correct answers of the diagnostic and intermediate test of CG
Resource: own production.

A quick look at figure 3 shows the difference between the respective tendencies of the correct answers for both groups. We can notice that the tendency line of the second test of the CG exhibits some improvement compared to the results in the first test (even though there are no

changes for questions 5, 6 and 10). However, the overall improvement (concentrated in questions 7, 8, 11 and 12) is compatible with the assumption that some familiarity with the basic definitions of logic might contribute to better higher-order thinking abilities.

EG and CG results

Since through the school year two students of the CG dropped out, we were unable to keep the number of students in both groups equal. However, this does not affect our work since in order to estimate improvement we compared the scores of each group internally. By doing so, we expect to avoid the statistical bias which can be obtained when we cannot apply the same instruments to an equal number of students.

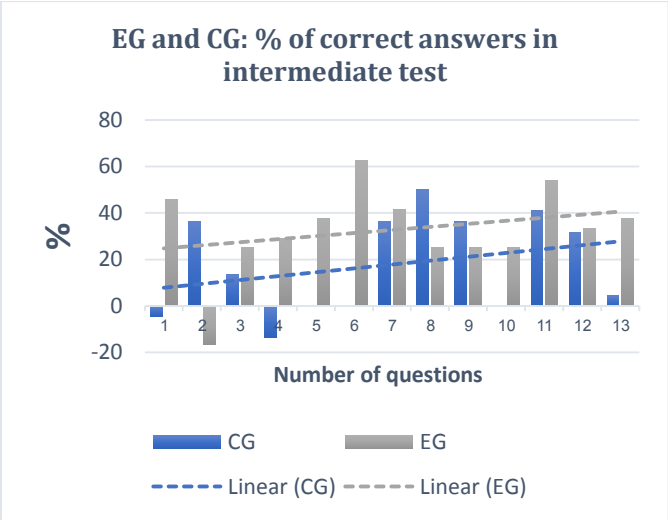

Figure 4. Percentage of correct answers of the intermediate test of CG and EG
Resource: own production.

Figure 4 shows that the results of the EG in the intermediate test were, overall, better than the scores of the CG, notwithstanding the fact the CG also improved its scores. The comparison using percentages corroborates our hypothesis in this work and illustrates that the treatment received by the EG makes a difference. Recall that the diagnostic test indicated that both groups had almost the same ability for the task so that it was appropriate to proceed with the quasi-experiment. The sharp differences indicated by the scores of each group in the second test show that there is no reason to reject our hypothesis.

Third research tool: final test

The final test, as the previous tests, was designed considering some simple logical relations like the ones exemplified in the traditional theory of immediate inferences. However, we made some adjustments to the structure of the final test by increasing the number of questions to 40 and prompting the students to produce more fine-grained reasons to justify some of their answers. Since good performance in this test also requires the ability to combine several inferences and to

support the answers with appropriate reasons it is not possible to get good scores answering randomly or by mere luck. So, familiarity with the material from the textbook and active participation in the argumentative exercises are a necessary condition for passing the test.

Figure 5 shows the results for both the EG and the CG. It is clear that the scores corroborate our conjectures since the group that received the treatment has a tendency line well above the tendency line of the control group, especially for the last group of questions that involved more complex reasoning abilities and were more difficult.

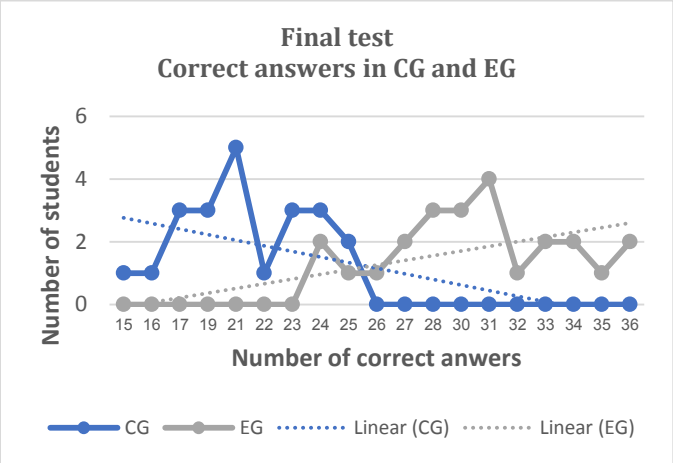

Figure 5. Correct answers of final tests of CG and EG
Resource: own production.

The test includes three types of questions. The first type requires the correct comprehension of basic concepts involved in the definitions used to make the appropriate distinctions and relations among categorical propositions and their relations, as defined in the traditional square of opposition. In this type we find questions like: if it is true that "all politicians are liars", what can be said of "some politicians are liars"? The second type of question involves a working comprehension of quantifiers and their scope besides the correct understanding of their equivalence and the ability to detect the quantity of a statement that is expressed in a general non-quantified way, for example: if it is true that "there is no football player who is not an athlete" what can be said about "Jones, the football player, is an athlete"? The third type of question explores the use of immediate inferences and their equivalence relationships, for example, "given that all philosophers are interested in human values, can we conclude that some people interested in human values are philosophers"?

For the last type of question, we include some exercises that necessitate the right use of immediate inferences and ask the student to combine this with the abilities involved in the first two types of exercise. For these reasons, the last type of question is more complex since it involves not only immediate inferences but also the relationships that are based in the logical square of opposition as well as the scope and logical equivalence between the different quantifiers. As mentioned above, it also involves the ability to support answers by giving reasons

based on the logical relations involved; for instance: if it is true that all cats are mammals what can be said about some non-mammals are non-cats? Or: suppose that being a college professor requires someone to lecture and being a researcher enables someone to be knowledgeable about the topic he investigates about and Smith is both a college professor and a researcher, can we conclude that Smith is both a lecturer and a person knowledgeable about the topic he investigates?

5. Conclusion

In the general methodology of critical rationalism experiment has the purpose of allowing the rigorous testing of conjectures. If the tests are not withstood, one has to frame bolder conjectures to attempt to solve the problems studied. As stated before, we claim that rational negative criticism improves critical thinking, hence, allows for fighting our own cognitive biases, personal prejudices and bad reasoning patterns.

In everyday life, we do not require the abilities of good and coherent reasoners, but it is not the same when we have to debate ideas, evaluate beliefs and examine theories. This suggests that, in the educational setting, it becomes desirable to offer the students some tools that help their thinking processes, that is, apply the principle of doubt and test severely even what look like their best ideas as well as their more entrenched certainties.

If our quasi-experiment to test the mettle and pertinence of the conjectures had yielded negative results, we would have had to renounce those conjectures and to frame bolder ones to make some progress in the aim of fostering the development of higher order thinking abilities. For the time being, we can conclude that the conjectures have withstood the tests and that our suggestions to improve critical thinking and reasoning abilities with high school senior students are correct.

As suggested in the introduction, in the literature it is quite common to find a definition of critical thinking as the sheer ability to argue for a particular view. This perspective leads to some kind of verificationism since each additional piece of confirming evidence increases our confidence. However, the humble stance of critical rationalism makes us aware that we cannot hope to know that we have obtained the truth but only approach it through error elimination.

The results obtained in this quasi-experiment, though including missed questions for certain particular tests, all in all do not falsify the conjecture that some familiarity with the basic elements of logic reinforces critical thinking, and are illustrated by the fact that the students in the EG performed far better in the task of identifying valid arguments and distinguishing good arguments from defective ones. Of course, our claim states that familiarity with the basic elements of logic is a necessary but not a sufficient condition for critical thinking. Based in these results, we recommend giving special attention to the teaching of logic in high school curricula. Most public high schools in Colombia do not include logic or related subjects in their curricula. And this explains the deep breach that separates public from private schools. Some of the latter have implemented programs such as *Philosophy for Children* that might satisfy our

recommendation. As we said above, the results of our work corroborate the conclusion that students benefit from some familiarity and basic training in logical abilities, creativity and criticism.

Annex 1

The main instrument used to collect data about the student's performance is a test that required short answers and a justification of the choice. During the process of empirical testing to evaluate our conjectures we applied three research tools: a diagnostic test, an intermediate test and a final test. These tests included questions formulated in such a way that they incorporated some elements from the theory of immediate inferences, basic distinctions about categorical propositions and quantification as well as a minimum ability to translate ordinary language sentences into categorical propositions. For these reasons our discussion of the results presupposes such a theory.

To effectively use language in argument requires the capacity to establish relationships among different propositions. Now, it is customary to understand categorical propositions as affirming or negating a certain relationship that holds among sets, groups or individuals. Since this type of proposition provides the raw material for the tests, to have a satisfactory performance one needs to have some understanding or working intuitions about: i) the scope of logical quantifiers, ii) relationships of inclusion or exclusion between the sets involved by the terms of the proposition, iii) a minimum ability to translate predicative sentences from the ordinary language to their respective categorical standard propositions, and iv) the distinction between necessary and sufficient conditions.

Besides the above conditions, the third test requires some familiarity with the basic elements of the theory of immediate inferences and some inference rules from first order logic. As explained above, the questions proposed necessitate a working knowledge of those basic concepts and the student needs to have a working understanding of the equivalence between logical quantifiers, even if they are not expressed in the typical form. Lastly, the questions involve the combination of immediate inferences and their main relationships as stated by the logical square of opposition.

References

Campbell, D. & Stanley, C. (1966). *Experimental and Quasi-Experimental Designs for Research.* Rand McNally & Company.

Copi, I., Cohen, C. & McMahon, K. (2013). *Introduction to Logic*. Rutledge.

Dewey, J. (1933). *How We Think: A Restatement of the Relation of Reflective Thinking to the Educative Process*. D.C. Heath & Co Publishers.

Dunne, G. (2015). Beyond critical thinking to critical being: Criticality in higher education and life. *International Journal of Educational Research*, Vol. 71, 86–99. https://doi.org/10.1016/j.ijer.2015.03.003

Ennis, R. (1987). A Taxonomy of Critical Thinking Dispositions and Abilities. In: J. Boyko & R. Stenberg (eds.), *Teaching Thinking Skills: Theory and Practice*. Freeman and Company.

Facione, P. (1998). *Critical Thinking: What it is and Why it Counts*. California Academic Press.

Fisher, A. (1988). *The Logic of Real Arguments*. Cambridge University Press.

García, C. (2005). *Cinco tesis sobre el estado del desarrollo de habilidades de pensamiento crítico en instituciones de educación superior de la región*. https://bit.ly/3wTCgTy

Giraldo, H. & García, C. (2019). The usefulness of critical rationalism in the theoretical and practical education field. *Revista Latinoamericana de Estudios Educativos*, 15(1), 91-110.

Harari, Y. (2018). *21 Lessons for the 21st Century*. Spiegel & Grau.

Harford, T. (2011). *Trial, Error, and the God Complex* [video]. YouTube. https://bit.ly/3TC1iAE

Lipman, M. (1974). *Harry Stottlemier's Discovery*. Montclair State Coll.; Upper Montclair; N.J. Inst. for the Advancement of Philosophy for Children.

Lipman, M. (1988). *Philosophy Goes to School*. Temple University Press.

Lipman, M., Sharp, A. & Oscanyan, F. (1980). *Philosophy in the classroom*. Temple University Press.

McNamara, D. R. (1978). Sir Karl Popper and education. *British Journal of Educational Studies*, *26*(1), 24–39. https://doi.org/10.1080/00071005.1978.9973506

Miller, D. (2005). Do We Reason When We Think We Reason, or Do We Think? *Learning for Democracy, 1*(3), 57-71. https://bit.ly/3CE2kpu

Paul, R. (2012) *Critical Thinking: What Every Person Needs to Survive in a Rapidly Changing World*. Foundation for Critical Thinking. Revised Third Edition

Pinker, S. (2021). *Rationality: What It Is, Why It Seems Scarce, Why It Matters?* Viking.

Popper, K. (1945). *The Open Society and Its Enemies*. Rutledge & Kegan Paul. 5th edition 1966.

Popper, K. (1963). *Conjectures and Refutations. The Growth of Scientific Knowledge*. Rutledge & Kegan Paul.

Popper, K. (1970). Normal science and its dangers. In I. Lakatos & A. Musgrave (eds.), *Criticism and the Growth of Knowledge* (pp. 51-58). Cambridge University Press.

Popper, K. (1998). *The World of Parmenides. Essays on the Pre-Socratic Enlightenment*. Rutledge.

Schlecht, L. (1989). Critical thinking courses: their value and limits. *Teaching philosophy*, 12(2), 131-140.

Siegel, H. (1988). *Educating Reason: Rationality, Critical Thinking, and Education*. Rutledge.

Siegel, H. (1989). The Rationality of Science, Critical Thinking, and Science Education. *Synthese*, 80(1), 9-41.

Stevenson L. & Haberman, D. (2004). *Ten Theories of Human Nature*. Oxford University Press.

Toulmin, S. (2003). *The Uses of Argument*. Cambridge University Press.