Estudios de Filosofía
ISSN 0121-3628 | ISSN-e: 2256-358X

Artículo de Investigación

Pablo Melogno's legacy: interpreting Kuhn's work on science education

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Received: 13/02/2024

Approved: 23/03/2024

Online First: 26/09/2024

DOI: https://doi.org/10.17533/udea.ef.356242

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Abstract

As this paper coincides with the first anniversary of Pablo Melognos passing, it delves into his profound contributions as a distinguished philosopher of science to the field of science education. Focused on his unique perspective shaped by an extensive exploration of Thomas Kuhn's philosophy, the paper aims to elucidate Melogno's distinctive insights into science education. The methodology employed involves a theoretical and exploratory analysis of Melogno's limited but qualitatively rich works on science education. Melogno's perspective on science education emerges in a deep engagement with Kuhn's philosophy. Despite shifts in his assessment of Kuhn's ideas, Melogno's core vision about science education remains steadfast throughout all his texts. By advocating a holistic understanding of the history of science, Melogno emphasizes the importance of cultivating critical thinking skills in students, while not forgetting to teach scientific concepts, methods, and theories. His stance rejects the notion of total ruptures in scientific paradigms as a way to avoid indoctrination. Furthermore, the paper proposes investigations into the relationship between Melogno's defense of partial ruptures, fostering a more nuanced historical perspective and promoting critical thinking in science education. In essence, Melogno's legacy extends beyond the footsteps of Kuhn, as he carved his own philosophical path, leaving indelible marks on the landscape of scientific thought.

Keywords

Kuhn′s philosophy, science education, educational critique.

How to cite this paper:

Garcia da Silva Oliveira, D. (2024). Pablo Melogno's legacy: Interpreting Kuhn's work on science education. *Estudios de Filosofía*, 72, pp. https://doi.org/10.17533/udea.ef.356242

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Artículo de Investigación

El legado de Pablo Melogno: interpretación del trabajo de Kuhn sobre la educación científica

Resumen
Como este artículo coincide con el primer aniversario del fallecimiento de Pablo Melogno, enfocamos en sus profundas contribuciones como un distinguido filósofo de la ciencia al campo de la educación científica. Centrado en su perspectiva única, moldeada por una extensa exploración de la filosofía de Thomas Kuhn, el artículo pretende dilucidar las ideas distintivas de Melogno sobre la educación científica. La metodología empleada implica un análisis teórico y exploratorio de los limitados pero cualitativamente ricos trabajos de Melogno sobre educación científica. La perspectiva de Melogno sobre la educación científica surge de un profundo compromiso con la filosofía de Kuhn. A pesar de los cambios en su evaluación de las ideas de Kuhn, la visión central de Melogno sobre la educación científica se mantiene firme en todos sus textos. Al abogar por una comprensión holística de la historia de la ciencia, Melogno enfatiza la importancia de cultivar habilidades de pensamiento crítico en los estudiantes, mientras no se olvida de enseñar conceptos, métodos y teorías científicas. Su postura rechaza la noción de rupturas totales en los paradigmas científicos como una forma de evitar el adoctrinamiento. Además, el artículo propone investigaciones sobre la relación entre la defensa de Melogno de las rupturas parciales, el fomento de una perspectiva histórica más matizada y la promoción del pensamiento crítico en la educación científica. En esencia, el legado de Melogno se extiende más allá de los pasos de Kuhn, ya que él labró su propio camino filosófico, dejando marcas indelebles en el panorama del pensamiento científico.

Palabras clave
filosofía de Kuhn, educación científica, crítica educativa.

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https://doi.org/10.17533/udea.ef.356242

Estudios de Filosofía
ISSN 0121-3628 | ISSN-e: 2256-358X

Brazilian edition of the book with translations from the Stanford Encyclopedia of Philosophy concerning the entries of Feyerabend, Popper, Kuhn and Lakatos.

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https://doi.org/10.17533/udea.ef.356242

Estudios de Filosofía
ISSN 0121-3628 | ISSN-e: 2256-358X

1. Introduction

The professor and philosopher of science at the Universidad de la República de Uruguay, Pablo Melogno, had dedicated his academic life to the study of philosophy and history of science in general, publishing papers on many topics and authors. He was particularly interested and known for his meticulous and creative work on Thomas Kuhn. Among his last most important publications about Kuhn, we can mention the Spanish translation of Kuhn's unpublished *Thalheimer Lectures* (2017); the most recent book edited with Leandro Giri and Hernan Miguel titled *Perspectives on Kuhn: Contemporary Approaches to the Philosophy of Thomas Kuhn* (2023), and important papers published in *International Studies in the Philosophy of Science* like "Kuhn's 'The Natures of Conceptual Change': the search for a theory of meaning and the birth of taxonomies (1980–1994)" (2023).

Nevertheless, Melogno's research went beyond one area of philosophy. Among his extensive research topics and interests, he worked with semantics, chemical revolution, Putnam, science communication and more. For the sake of this paper, it should be mentioned that he also worked with science education in an earlier stage of his career. Melogno has developed a view on science education based on his refined interpretation and research about Kuhn. Because of this fine work on Kuhn, Melogno has made excellent reflections for education, which is also helpful in understanding his view on Kuhn.

In this sense, our aim here is twofold. First, to introduce and explore Melogno's contribution to science education, arguing how and why it carries a relevant contribution to any work that intends to understand science education nurtured from a highly accurate and innovative work on Kuhn. Second, we will reveal and explore Melogno's view about what the goal of science education is.

Our methodology in this work is critically oriented by a theoretical and exploratory analysis of Melogno's work on science education. In this sense, considering that, unfortunately, Melogno passed away in 2023, and that his work on science education was in its early stage, our research will be quantitatively limited. However, we believe it to be qualitatively fertile. Thus, we will only include in our database three main texts on education; those in which Melogno is the sole author, and the texts are a full body paper or chapter.

https://doi.org/10.17533/udea.ef.356242

This paper is structured into four sections: Section 1, titled "Introduction", where we establish our topic and objectives, and justify this paper. Section 2, titled "Revisiting Kuhn's Science Education", checks the arguments of dogmatic education in Kuhn. Section 3, titled "Melogno's View of Science Education", introduces Melogno's view on the goal of science education. In section 4, "Conclusions", we will make our final remarks and point to future research around the topic.

2. Revisiting Kuhn's science education from multiple points

Melogno is known for his extensive research on Kuhn's philosophy, but his work on scientific education is often overlooked. Nevertheless, his ideas and implications regarding general education and science education are equally valuable. Melogno's expertise on Kuhn's philosophy provided a unique perspective on science education, making his work relevant to both Kuhn's studies and science education.

His contributions to Kuhn's studies are of an international level, and his work on science education is accurate and innovative despite being less well-known. Additionally, Melogno's research corrected some of the misunderstandings about the implications of Kuhn's work for education that had been put forth by other philosophers. Let us explore Popper's view of Kuhn's education and its reflection on other philosophers, like Bailey.

Melogno's work on education is relevant because his approach to science education reflects the view of a highly qualified scholar of Kuhn, with the originality and brightness that only a true Kuhn's scholar can produce (Melogno, 2013a, 2013b, 2015). For instance, on this subject, debated with other brilliant scholars around the topic of education, we found in the paper "Dogmatismo y Adoctrinamiento" (2013a) that Melogno opposed to Richard Bailey (2006) and Darrell Rowbottom (2006) on the matter of what kind of science education Kuhn's philosophy supports. Bailey (2006) and Rowbottom (2006) have sustained the idea that a Kuhnian education is dogmatic, and it indoctrinates students due to their view of Kuhn's processes of scientific revolutions and periods of normal science. These authors address the issue of an indoctrinated

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education by arguing that Kuhn's view on the structure of scientific periods of change saves the current paradigm from criticisms during periods of normal science. For instance, Bailey commented that Kuhn's idea of normal science education looks like a religious rite of passage. In one paragraph, Bailey says that:

> The education of the normal scientist is, according to Kuhn, 'an initiation into an unequivocal tradition' (1977, p. 352). Students are not introduced to the history of their discipline, nor to original research (until they start their own research as postgraduates), since only the currently accepted results are of relevance to the initiate members of the scientific community. Kuhn presents a rather unattractive image of science education; one more akin to certain forms of religious education (Bailey, 2006, p. 14).

Looking carefully at the quote, we notice that the argument against Kuhn's normal science education is that Kuhn's education is akin to religious approaches of indoctrination. It does not reflect the attractive image that science supposedly should have. Bailey says that such an educational model, based on a rigid periodization of stages of developments in science, restricts those students that live in normal science periods to only current results of their scientific disciplines. Under such an understanding, Kuhn would be advocating for students' initiation into only currently accepted theories, results, and methods. Moreover, since the history of science would not be included into this initiation, it becomes in the end an initiation into an unequivocal tradition. Bailey called this model of education a *transmissionist approach*, in which students are introduced only to the conceptual framework that plays a present role in making them comprehend the current state of science and world (Bailey, 2006). In his words, it is an approach that "presumes that tradition, custom and key beliefs are presented as beyond doubt and criticism" and that they are employed as "facts that are simply above consideration" (Bailey, 2006, p. 14). This is why, from an educational point of view, Bailey argued that Kuhn's model of normal science education would be non-critical. From his perspective, Kuhn's transmissionist education is a non-critical approach, according to Bailey, "I think, beyond doubt" (Bailey, 2006, p. 16). Such a characteristic of non-critical approach in Kuhn's education model goes beyond the simple transmissionist problem of scientific content. It becomes a means of indoctrination, which, just like religion, seeks

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to ensure "cultural continuity and preparing individuals to perform predetermined social roles" (Bailey, 2006, p. 14).

As the above quotation indicates, the argument against Kuhn's model of normal science education holds that Kuhn's education, i.e., "Normal science education, as portrayed by Kuhn, seems to qualify for the label 'indoctrination' on all grounds." (Bailey, 2006, p. 16). On this matter, it is true that Bailey brings new and strong arguments to the table, but his accusation is old. He himself mentions that Kuhn's model of education as non-critical is an objection that comes from past philosophers and science educators. For instance, Bailey quotes the following comment of Popper in the famous 1970 meeting:

> "Normal" science, in Kuhn's sense, exists. It is the activity of the nonrevolutionary, or more precisely, the not-too-critical professional ... The 'normal' scientist, in my view, has been taught badly. I believe ... that a teaching on the University level (and if possible below) should be training and encouragement in critical thinking. The 'normal' scientist, as described by Kuhn, has been badly taught. He has been taught in a dogmatic spirit; he is a victim of indoctrination (Popper, 1970, pp. 52-53).

A noteworthy point to underscore in this passage used by Bailey is that Popper actually acknowledged his debt to Kuhn concerning what happens in periods of normal science. In the previous quote, Popper says that he is grateful to Kuhn "for pointing out the distinction [periods of science], and for thus opening my eyes to a host of problems which previously I had not seen quite clearly" (Popper, 1970, p. 52). Popper acknowledges the existence of normal science in Kuhn's sense, and that Kuhn opened his eyes to it and its problems. For instance, in another passage, he argues that "what Kuhn has described [normal science] does exist, and that it must be taken into account by historians of science" (Popper, 1970, p. 52). So, what Popper is saying is that whether or not historians approve of what Kuhn described, they should work from it, given its existential accuracy. In short, to Popper, Kuhn's description was correct. So, if a person does not like Kuhn's description, she should bring that sentiment to scientists and scientific practice, not to the person who made the mechanism explicit by describing it. In addition, Melogno draws our attention to one thing: philosophers should be fairer to Kuhn's actual view of normal science.

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However, this is a mistake that even Popper (1970) committed, which ironically is the same mistake that he commonly accuses his critics of making towards himself. It seems that Popper did not understand Kuhn's educational model very well, and the same happened to those that followed him. That is why Melogno calls us to better understand how paradigms correlate to normal science and the consequences of normal science to education.

The question, then, is not a disagreement between Popper (and Bailey) and Kuhn about the state of affairs concerning Kuhn's normal science. Popper already acknowledges Kuhn's descriptive precision.

The question is whether what Popper (and Bailey) said about Kuhn's model of normal science and science education is what Kuhn actually wrote about it. As Melogno reiterates, that matter is not whether Kuhn's characterization of normal science is accurate, which Popper accepts as true. The question is whether Popper and Bailey got Kuhn's view right when they were building their accusations of Kuhn's dogmatic education (Melogno, 2013a). Under Popper's view, such a normal science education will produce only "applied scientists", i.e., a practical solving-puzzle person, who stands in contrast with what science education should produce, a "pure scientist", i.e., a critical thinking person (Popper, 1970, p. 53). Bailey basically reinforces Popper's arguments.

That being said, it is true that in Kuhn's description of normal science, which Popper agrees to be accurate, educators and scientists do teach science students towards the learning of techniques and perform daily routines. Equally important is that, when viewed superficially, Kuhn's definition of normal science may seem to leave no room for critical thinking. To illustrate this potential pitfall of a superficial understanding of Kuhn's view, Melogno (2013a, p. 10) cites the following Kuhn's paragraph on the nature of normal science as a mopping-up operation:

> No part of the aim of normal science is to call forth new sorts of phenomena; indeed those that will not fit the box are often not seen at all. Nor do scientists normally aim to invent new theories, and they are often intolerant of those invented by others (Kuhn, 1996 [1962], p. 24).

Kuhn says that normal science is basically a mopping-up operation which most scientists are ordinarily engaged, in which guides scientists to work on articulations of those phenomena and

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theories already offered by the paradigm. Normal science is an enterprise that has "drastically restricted vision." (Kuhn, 1996 [1962], p. 24). Thus, on one hand, Kuhn did say that about normal science as an intolerant operation, but on the other that is not all. If Kuhn sustains that normal science is a part of science that is intolerant towards novelties, how can we explain the fall of old theories and the emergence of new ones pushed by scientists living, studying, and engaged in what Kuhn described as normal science? How is this reconciled with the intolerance in the previous quotation? Kuhn says that:

> New and unsuspected phenomena are, however, repeatedly uncovered by scientific research, and radical new theories have again and again been invented by scientists. History even suggests that the scientific enterprise has developed a uniquely powerful technique for producing surprises of this sort. If this characteristic of science is to be reconciled with what has already been said, then research under a paradigm must be a particularly effective way of introducing paradigm change (Kuhn, 1996 [1962], p. 52).

In other words, although scientists working in normal science are primarily worried about a "small range of relatively exoteric problems", on the other hand, Kuhn proceeds to say more about normal science. Kuhn's answer to those questions is clear: inside the progress of normal science lies the mechanism for emerging new theories and facts. He says: "That is what fundamental novelties of fact and theory do. Produced inadvertently by a game played under one set of rules, their assimilation requires the elaboration of another set." (Kuhn, 1996 [1962], p. 52).

Kuhn remembers that such characteristics of normal science, like being a mopping-up operation, could alternatively be "defects" (Kuhn, 1996 [1962], p. 24). So to really understand even normal science, one must see history from a more broad perspective, such as when we are looking to date the discovery of oxygen (Kuhn, 1996 [1962], p. 53-55).

> Clearly we need a new vocabulary and concepts for analyzing events like the discovery of oxygen. Though undoubtedly correct, the sentence, "Oxygen was discovered," misleads by suggesting that discovering something is a single simple act assimilable to our usual (and also questionable concept of seeing). (Kuhn, 1996 [1962], p. 55).

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So, Kuhn opens the road to rethink how normal science could work, especially from an educational point of view. Thus, to say that Kuhn's philosophy is dogmatic through and through is to lose sight of the big picture of his philosophy. Second, our observation fits perfectly well with what Melogno argues against a dogmatic description of normal science, and by extension, science education. Melogno remembers that for Kuhn:

> Lack of questioning about the revisioning parameters of a paradigm is an indicator of professional security, as it accounts for the effectiveness with which at a certain historical moment a paradigm manages to solve the problems of its domain. Conversely, the fact that the parameters of the paradigm are exposed to questioning by the scientific community is a consequence that some sector of the paradigm having encountered an anomaly that it cannot handled (Melogno, 2013a, p. 11, translated from Spanish).

Melogno calls our attention to the fact that, according to Kuhn, normal science is not just about rules but also about how the scientific community interacts, debates, finds common basis, and works out their disagreements, i.e., "Normal science can proceed without rules only so long as the relevant scientific community accepts without question the particular problem-solutions already achieved" (Kuhn 1996 [1962], p. 47). In other words, there are moments when normal science advances with and without questioning. Moreover, the way these moments come up and change and are affected by criticism will, as told us Melogno, depend on how much successful a paradigm is. A normal science without anomaly would not produce change. However, there is not such a thing.

Therefore, this is the moment to question how we should teach science students through Kuhn's perspective. Is normal science "not-too-critical" activity, and even if normal science is defined that way, does Kuhn think it should be? The idea that Kuhn's normal science is synonymous of a dogmatic activity is an interpretation followed by many, Bailey included, but also objected by others, like Melogno. Even Kuhn himself says that scientific textbooks are generic and that his "essay attempts to show that we have been misled by them in fundamental ways" (1996 [1962], p. 1).

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Melogno says that for Kuhn, the idea of paradigm as normal science does not mean that we have to avoid making any criticisms to the current paradigm. Melogno (2013a) argues, against Bailey and extensively against Popper, that if a person accepts Kuhn's model of normal science, it follows from such a characterization that scientists should offer their criticisms at all moments of scientific work, and that a resulting science education welcomes critical thinking. We must keep in mind that Kuhn is describing the state of affairs of normal science, although he is not turning such a description into a conformation to it, or that such a description does exclude critical thinking at all times of normal science.

Kuhn's use of the term 'normal' in 'normal science' does not imply a rigid adherence from him or from those scientists involved in normal science. It is essential to remember that "the scientific community" is not a monolithic entity because anomalies are a reality in all paradigms. There are debates and disagreements within scientific communities that share a paradigm, and although these divergencies are more often seen in social sciences than in natural sciences, that does not mean that we have a homogeneous scientific community free of disagreements (Kuhn 1996 [1962], p. x). So, if for Bailey, Kuhn's idea of normal science does not tolerate criticism beyond doubt, contrary to that, for Melogno, this is not a view beyond doubt. Melogno says:

> Kuhn also pointed out that it is essential to analyze science education to understand how paradigms determine normal science (1962, 85), so the idea that certain basic elements of paradigms must be preserved from criticism is not introduced by Kuhn for the purposes of a specific conceptualization of science education, but rather constitutes a central component of his characterization of normal science (Melogno, 2013a, p. 11, translated from Spanish).

With this quote, Melogno reminds us all of what actual scientific practice and research look like under Kuhn's view, and what philosophers of science can do from it. He also shows a fine-tuned difference between describing processes and events as objectively as possible and, on the other hand, the prescription of it. According to Melogno, Kuhn has not defended a noncritical scientific education, neither does normal science introduce a dogmatic perspective. Furthermore, even if one interprets Kuhn, as Bailey and Popper did, as if normal science were only "not-too-

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critical thinking", it would not mean that Kuhn also defended a science education view based on a non-critical approach.

Melogno (2013a) tells us that Kuhn's scientific education acknowledges the existence and consequences of normal science. This acknowledgment is something that not even Popper disagrees with. However, this acknowledgment is something completely different from (a) understanding what Kuhn actually means by normal science; and (b) understanding what Kuhn aimed as a desirable science education, its challenges for science teachers and professors living in a paradigm. Melogno (2013a) reminds us that in Kuhn's model, while some scientific claims are not criticized, it does not follow that science has non-criticizable claims at all. In reality, Melogno tells us that a characterization of an education understood as a non-dogmatic practice, such as the one we find in Kuhn's work, is based on a characterization of science itself as non-dogmatic. More than that, Melogno mentions how Putnam and Lakatos stand up for an idea of critical thinking in normal science activities, similarly to Kuhn's nuances in criticism of scientific claims. On this Melogno wrote that:

> Both Putnam and Lakatos have contributed to the idea that science does not work by exposing all of its statements to criticism at the same time, but that this does not mean that some of them are intrinsically irreversible, nor that their revision is a symptom of professional insecurity or the advent of a crisis (Melogno, 2013a, p. 11, translated from Spanish).

Indeed, this view on scientific activity is one where, at the same time, we need some basis to start working on it. However, as we advance, we can gradually review and replace old ones with new ones if need be. In this sense, Melogno has continually debated Kuhn's view on science education from his own sophisticated viewpoint of Kuhn's philosophy, bringing new approaches and solving possible misunderstandings about it.

So far, we have shown how a common objection to Kuhn's philosophy can be avoided, such as that he supports a dogmatic education and from where it came. Now we will explore in additional texts what Melogno's proposal of science education is and how it differs from Kuhn's science education.

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3. Melogno's View of Science Education

While Kuhn's work significantly inspires Melogno's proposal of science education, he is not the sole influence. This is particularly noteworthy as Melogno's publications about education correspond to his initial years of research, even before the completion of his Ph.D. Yet, we can discern some fundamental directions in his thoughts about science education and how, although inspired by Kuhn, they also carry the imprint of other authors who, at some point, contributed to Melogno's unique identity.

In all his texts about science education, we find a view of scientific teaching where students should at the same time be prepared to learn actual science but also to understand its history, philosophy, and nature and to debate its present and the future. It is generally a science education built from and towards critical thinking. For instance, in "Dogmatismo y Adoctrinamiento" he says: "It is concluded that the appeal to these models seems to provide an attractive strategy to reconcile historical evidence regarding how science works with a conception of education that gives a central place to critical capacity." (Melogno, 2013a, p. 1, translated from Spanish). Melogno's work on education was committed first and foremost to critical thinking above any philosopher.

3.1. The Aim of Science Education in the Paper "Límites y condiciones del sentido crítico en la educación científica"

In another paper, "Límites y condiciones del sentido crítico en la educación científica" (2013b), Melogno continued to investigate the topic of science education and criticism, although now in the company of Popper as an advocate of critical thinking. It is under such research object that his paper above mentioned was published as a book chapter, that resulted from the colloquium "Desafíos de la educación científica" in Uruguay (2013). In this work, he also returns to the topic of normal science as a means of teaching and learning scientific theories and history of science. However, Melogno also offered some critique of Kuhn's ideas. Nonetheless, as evident in his previous paper, he demonstrated that, in practice, it is impossible to subject all scientific claims to

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simultaneous criticism. This is a position consistent with Melogno's earlier argument regarding Kuhn. If we were to assume that all scientific claims should be open to criticism at all times, it would render the very notion of progress impossible. Thus, Melogno says: "Now, all these characteristics seem to account for the limits of the critical exercise, and the impossibility of postulating it as an unrestricted exercise, rather than a dogmatic element present in science" (Melogno, 2013b, p. 134, translated from Spanish).

In his academic papers published in 2013, Melogno discussed the prevalent misconceptions about critical thinking in education. According to him, it is a common misconception that science requires constant criticism of all theories at all times. However, he emphasizes that calling this a misconception does not imply that science is dogmatic *per se*. On the contrary, Melogno strongly believes that critical thinking is indispensable for any scientific activity to hold any value. He asserts that the principles of objectivity and rationality adopted by science can only be upheld and advanced through the practice of critical thinking. In other words, critical thinking is not just an optional tool, but an essential part of scientific inquiry that allows for a more nuanced and accurate understanding of the phenomena under investigation. He says that:

> On an intuitive level, the critical sense can be linked to the claims of objectivity that usually accompany science. Since science is an activity that seeks to account for the world objectively, any scientific hypothesis can be reviewed and exposed to criticism based on the experimental material available (Melogno, 2013b, p. 117, translated from Spanish).

If this is the case, dogmatic education becomes incompatible with Melogno's view of science as naturally critical. According to Melogno, in its *most fundamental way*, "critical sense refers to the methodological attitude of taking every scientific statement as fallible or susceptible to revision" (Melogno, 2013b, p. 117, translated from Spanish). This is how scientific knowledge must see itself: as always fallible, and this assertion is a widespread position. However, in this sense, it issues an emancipatory lesson from the history of science, one that goes beyond our textbooks and their view as a "repository for more than anecdote or chronology" (Kuhn, 1996

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[1962], p. 1). Any scientific education that intends to understand and teach science cannot move forward without carrying the weight of a critical attitude, of a fallible scientific knowledge that is a "result of this always unfinished dialogue with experience" (Melogno, 2013b, p. 117, translated from Spanish). Therefore, we come to the point where Melogno clearly states his view of what the aim of science education should be:

> If these terms are defended, it can be thought that the development of critical capacity is one of the fundamental objectives of scientific education, involving not only the specific processes of knowledge appropriation, but the general image that scientists forge about the nature of his discipline (Melogno, 2013b, p. 117, translated from Spanish).

It is important to not only teach students scientific knowledge such as history, theories, methods, models, and techniques, but also to investigate the nature of science as scientists themselves practice it and explore its interdisciplinary connections. Additionally, there must be a critical dialogue between these two aspects of science education. Since scientific knowledge and its image by scientists are incomplete and fallible, it is essential to provide students with an education in science that emphasizes critical thinking for their development. Melogno advocates for a middle ground between Kuhn's and Popper's views concerning critical thinking. He says:

> Much more fertile as a strategy seems to be the alternative of considering that criticism has a place of importance in science and scientific education, surely much more relevant than that given to it by Kuhn, although much more modest than that given to it by Popper. (Melogno, 2013b, p. 134, translated from Spanish).

Melogno's contribution to science education lies in his proposal for a more nuanced role for critical thinking. This role, he argues, is both more significant than Kuhn's defense of normal science activity and more modest than Popper's falsificationism. What Melogno is actually referring to is an idea which we have already explained: *restricted criticism*, where there is not such thing as criticism of all at once. Rather, it acknowledges that criticism has its place and time in scientific progress but also recognizes the need to suspend criticism temporarily for the sake of

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research momentum. Melogno supports his argument by pointing to historical cases, such as Newton's celestial mechanics, where the temporary suspension of criticism did not lead to dogmatism. Using the case of the Newtonian predictions that were not confirmed, he says:

> The critical contrast of the hypothesis of the new planet was only possible under the uncritical assumption of the Newtonian framework, and if these types of processes are representative of scientific dynamics, then it is not possible to label it of a dogmatic just because some theoretical levels are exposed to criticism and others are preserved (Melogno, 2013b, p. 134, translated from Spanish).

In other words, Melogno shows us that sometimes theoretical interactions, experiments, and propositions of new alternatives must start, at least temporarily, from some assumptions of what is already established in an uncritical manner. Even revolution and crisis start from paradigms and some temporary and selectively uncritical assumptions. To state this in another way, although sometimes critical thinking is put aside with respect to some parts of a specific scientific research, that does not mean that science is in itself dogmatic or that such a specific research case moves on uncritically from beginning to end. Science education still employs critical thinking, but at the same time, it acknowledges that scientific research development should not be paralyzed by critical thinking. Such a view on science and the role of criticism in it influences a Kuhnian science education, its aims, and the discussion of the discipline of science education from a Kuhnian perspective.

Based on this connection between science and criticism, Melogno wrote what we think to be his most mature text on the matter, titled "Thomas Kuhn y la educación científica" (2015). In this text, the author points out two kinds of debates inside Kuhn's philosophy for the field of science education, which, according to Melogno himself, "we will seek to show how his [Kuhn] vision of scientific education plays a more important role in his work than has usually been attributed to him" (2015, 98, translated from Spanish). Let us explore this debate now in detail and see how we can reveal Melogno's own take on science education.

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3.2. The Aim of Science Education in the text "Thomas Kuhn y la educación científica"

In the book chapter "Thomas Kuhn y la educación científica" (2015), Melogno says that the role of science education in Kuhn's philosophy occupies a more meaningful space than it is commonly thought. This is not only an outstanding statement, one that separates Melogno from all of those scholars that do not think in that manner, but it is one for those interested in Kuhn's philosophy. Those who from now on will have to give more attention to this aspect of Kuhn's work. Interestingly, what makes this work different from the other are two things. First, Melogno ends it with an open reflection about how we should approach Kuhn's view of science and science education as if we should take one as being an extension of the other, or as incompatible parts. Second, in a clear demonstration of Melogno's own path, he started for the first time to criticize Kuhn's position and its consequences on science education. By doing that, Melogno marks his position, which is not only coherent with previous texts but also audacious (as Popper recommended). Melogno reached his position by criticizing Kuhn and supporting it with part of Fuller's reflections. Melogno argues that science education must support a critical formation in order to make it consistent with its history of science and progress (practical, humanitarian, and epistemic). He suggests that students should learn about the long and divergent history of science, as well as the factors that influence scientific inquiry. This approach helps students understand that scientists are not isolated in an ivory tower but rather are influenced by extra-scientific factors.

In this sense, Melogno revisits an old problem that still revolves around dogmatism in Kuhn's description of how paradigmatic shifts happen, its consequences, and how scientists can be trained (Kuhn, 1962). We already approached this problem above and how other philosophers, like Popper and Bailey, reacted. Here, Melogno reinstates that old problem in a very stimulating way. He says:

> The fact that each paradigm entails its own way of organizing experience, added to the idea that conceptual changes in science can be explained as changes in gestalt organization, led Kuhn to think that entering and belonging to a scientific community are based on a sustained process of perception training, which is why scientific education will be assigned a fundamental role in this training function. […]. Based on this, it is worth asking, what is the most functional type of

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> education for this image of science? How should scientific instruction be organized if its objective is a functional insertion into the paradigm? (Melogno, 2015, p. 100, translated from Spanish).

The question being asked assumes a certain direction for scientific education, its objectives, methods, etc. Generally, science education is conducted within a specific setting (like biology, or physics, or chemistry), timeframe (with some shared epistemic and functional assumptions in the community), and with a specific purpose (depending on what educational level we are teaching). While it is possible to deviate from this context on occasion, there are contextual limits to how far this can be done. Normal science education is designed to train future scientists within a specific framework of a discipline. Kuhn seems to assume that it would make no sense that when teaching science, focused on instructing science students to do scientific research, like biology, these students should be educated to see the world from the perspective of another discipline, like theology and from another theory, like the theory of intelligent design. So, Kuhn is thinking on functional science education, one that follows the accepted paradigm guidelines, and scientific community rules.

Scientific education takes place within a discipline (science), and initially, students are taught to accept some fundamental theories and principles without questioning them. Not because they cannot question them but because some epistemic value must be granted to them for better learning of how to practice science. This provides a foundation for practical training within that scientific community, where sometimes you take a theory as true in order to test it or to explore its correlations with other theories. However, we must remember that scientific education is more comprehensive than this practical aspect. As Melogno said:

> Kuhn's considerations on scientific education largely answer the question about how a scientist learns to see the world from a certain paradigm and, along these lines, he points out that the scientist does not structure his perception analytically, but rather does so holistically, establishing interrelationships that make up a global vision of his disciplinary field (Melogno, 2015, p. 100, translated from Spanish).

https://doi.org/10.17533/udea.ef.356242

Estudios de Filosofía
ISSN 0121-3628 | ISSN-e: 2256-358X

According to him, a scientist should be trained not only within the framework of the accepted paradigm but also within the broader context of his or her discipline and the community to which he or she belongs. The scientist should be able to comprehend the discipline as a whole, along with all of its interrelationships. Therefore, a scientific education must encompass not only the current scientific content of that discipline. Naturally, such an ability requires interdisciplinary links, such as those between science and philosophy and the history of science.[1] Regarding this, Kuhn continues in the same page:

> Even from history, however, that new concept will not be forthcoming if historical data continue to be sought and scrutinized mainly to answer questions posed by the unhistorical stereotype drawn from science texts. Those texts have, for example, often seemed to imply that the content of science is uniquely exemplified by the observations, laws, and theories described in their pages. Almost as regularly, the same books have been read as saying that scientific methods are simply the ones illustrated by the manipulative techniques used in gathering textbook data, together with the logical operations employed when relating those data to the textbook's theoretical generalizations. The result has been a concept of science with profound implications about its nature and development (Kuhn, 1996 [1962], p. 1).

Textbooks typically present the nature of science from the perspective of the current paradigm, with only a brief historical overview. This approach serves the purpose of reinforcing the idea of a single, continuous tradition of scientific progress, while ignoring the impact of scientific revolutions and their consequences. Melogno's work sheds light on the "invisibility thesis" of scientific revolutions in textbooks, prompting some intriguing reflections:

> Likewise, the textbooks include a historical introduction to the discipline and its heroes, awakening in its aspirants and members of the community the feeling of belonging to a tradition that has lasted over time. But Kuhn is adamant that "the tradition derived from textbooks, in which

[1]Feyerabend (1993) also proposes this kind of relationship between science, philosophy, and the history of science as advantageous to science students. This and other ideas are further developed in a chapter by Oliveira (2024).

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> scientists come to feel like participants, never actually existed" (Melogno, 2015, p. 102, translated from Spanish).

The tradition never existed because the replaced paradigm is assumed to be incommensurable with the new one. The textbooks from which students get their introductory courses usually do not point that out. The books for these courses *make scientific revolutions invisible* to build a sense of belonging and continuity in students. However, in reality, what is happening is a rupture—one that is not only part of scientific education in normal science but also attends to the interests of solving the problems posed by the accepted paradigm. As Kuhn himself points out:

> No wonder that textbooks and the historical tradition they imply have to be rewritten after each scientific revolution. And no wonder that, as they are rewritten, science once again comes to seem largely cumulative. […]. The depreciation of historical fact is deeply, and probably functionally, ingrained in the ideology of the scientific profession (Kuhn, 1996 [1962], p. 138).

It is common for traditional science education to adhere to an accepted paradigm to create a functional community with an ideological goal. This adherence does not need to be dogmatic; it suffices to be only functional. This partial commitment allows the community to eventually reject the paradigm when the scientific community engages in widespread discussion and critique of the established paradigm. As Melogno observes:

> It is clear that for Kuhn only in this way can a scientific community survive, because the times in which the problems that are legitimate to solve, and the rules that should be used, are discussed precisely the times in which communities have lost their cohesion and are at risk of survival (Melogno, 2015, p. 103, translated from Spanish).

As Kuhn points out, there are periods of open, unrestricted dialogue and periods where discussion is more confined, as seen in normal science. In normal science, an established paradigm is fostered. However, during times of crisis and revolution, criticism and discussion take center stage, addressing the challenges that arise during normal science, such as disunity in the

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community around a paradigm. To contribute to science, one must first master the theories, methods, and models. Hence, science education focuses on teaching the paradigm, but not only that. Consequently, there will be instances when disunity surfaces, and criticism intensifies. Kuhn posits that only a student who understands and is familiar with scientific theories can evaluate them with enough depth. However, Melogno says that this reflection leads to a paradoxical answer because:

> [w]hile the student is learning the paradigm, its components seem esoteric to him, in that he is not sufficiently familiar with them. For this reason, he is unable to evaluate what he only partially understands. But when he has managed to completely assimilate the paradigm, the ontological and methodological commitments that compose it, the paradigm uncontrollably shape his vision of the world and guides the terms in which he evaluates the legitimacy of a problem or the validity of a solution. For this reason, after he has learned to work in a paradigm, it is no longer within his power to evaluate it either (Melogno, 2015, p. 104, translated from Spanish).

If this is the case, it means that Popper and Bailey were right in criticizing Kuhn's science education as dogmatic, as we saw in previous papers. Nonetheless, Melogno finds a way out of this embarrassing situation. The sentiment of belonging to the scientific community is embedded in education and textbooks' historical depreciation and ideological structure. This depreciation, according to Melogno, creates an image of complete rupture and dogmatism in normal science education. However, as Kuhn reminds us, science does not have only one value, such as community belonging. Fact and truth are both also scientific values, and as such, they should be observed: "The depreciation of historical fact is deeply, and probably functionally, ingrained in the ideology of the scientific profession, the same profession that places the highest of all values upon factual details of other sorts" (Kuhn, 1996 [1962], p. 138).

Kuhn acknowledges that science is a tapestry of multiple values, and factual truthfulness to our historical records is one of them. Science has memory, and it develops through various stages. In this sense, once science education teaches history, it is in that part that we find the process of rupture between paradigms. Nevertheless, must this rupture be complete (total) to better describe

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a complete Kuhnian picture of the relationship between science and education? Melogno believes that if we reject the perspective of complete rupture between paradigms, science education will no longer host a deformed ideology of historical depreciation. He says:

> Since the process of dehistoricization of textbooks comes, according to Kuhn, from the need to generate in the scientist a feeling of continuity where there is none, *the ideological and deforming character of scientific education is only such if it is accepted that the rupture of current paradigms with past ones is total* and, therefore, the sense of belonging to a tradition can only be maintained through ideological deformation. That is to say, the particular function and scope that Kuhn gives to scientific education can only be accepted if the Kuhnian characterization of scientific revolutions is accepted in all its terms and, ultimately, if it is accepted that revolutions constitute transitions between incommensurables (Melogno, 2015, p. 105, *italics added*. Translated from Spanish).

Nonetheless, what if we take the alternative path, one where the rupture between the old and new paradigms is not complete? Melogno explores the avenue where two paradigms, old and new, share at least one element. In this way,

> when a change in theory occurs, large portions of previously accepted knowledge are discarded, without completely breaking with pre-established traditions or another prior knowledge. […]But if it is considered that the rupture with previous traditions is not total, then the need for ideological inculcation is not so intense, nor is the deformation effect exerted. Therefore, the feeling of belonging to a tradition that extends back in time is not entirely a product of ideological deformation, as Kuhn claims. (Melogno, 2015, p. 105, translated from Spanish).

Melogno says that if we take actual scientific practice into consideration, we can see that there is no such thing as total rupture between two traditions. For instance, Galileo and Kepler were revolutionaries in one sense. On the other hand, "they were just as justified in seeing themselves as belonging to the same tradition as Euclid, Pythagoras or Archimedes." (Melogno, 2015, p. 105, transl from Spanish). In this sense, once we argue that there is no such thing as a complete rupture

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between two traditions, it is consequently possible to have a science education without indoctrination. Such indoctrination results from a complete rupture fed by historical depreciation. Melogno argues that without historical depreciation, students would acquire certain immunity from the indoctrination of normal science since a paradigm rupture would not be observed. The scientific community is not an isolated institution but shares a more comprehensive and critical history with other actors, such as extra-scientific ones. Once we reject a complete rupture of paradigms, this comprehensiveness and the subsequent relationships between science and other actors become available to students for further scrutiny (Melogno, 2015, p.106). Here, Melogno follows Fuller's arguments that Kuhn's view of science could lead to indoctrination, at least if we embrace Fuller's interpretation of Kuhn. Based on Fuller's critique of Kuhn, Melogno argues that the scientific community is not separated from society and its other institutions. Kuhn's view of science as a mopping-up operation, as the main work of scientists in normal science, is dependent on extra-scientific factors, such as industry, society, and politics (Melogno, 2015). Therefore, since science and its paradigms are also connected with these extra-scientific factors, Melogno concludes that "it can be thought that the different aspects of the production of science are not immune to critical scrutiny, and neither should they be" (Melogno, 2015, p. 107, translated from Spanish).

In other words, if we follow the Popperian view of what Kuhn said about normal science and science education, it can be said that Kuhn does not support a critical scrutiny of science. However, Melogno claims that there are other possible interpretations with different outcomes. He himself has done that before, as we have shown in previous texts when he advanced the view that criticism cannot be sustained in science unrestrictedly. Conversely, when we consider that the scientific community is still an institution with its own rules and legitimacy, it is only possible to sustain any form of science education by following what this community considers valid. So, a halfway solution between what Kuhn and Fuller argued is proposed by Melogno, who gives history a more relevant role for the educational purposes that he introduces. According to our interpretation of Melogno's work, a *fundamental* goal of science education needs to focus on critical thinking, fed by a solid historical formation as an inherent part of good science teaching. Such education needs to be compatible not only with the current scientific standards and goals, but also with a view of

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science as a complex subject with a long history. Thus, although Melogno makes a strong criticism of Kuhn's view of normal science at the end of his educational research, he also states that Kuhn's philosophy is "made up of several dimensions that are strongly integrated with each other and they are not easy to isolate." (Melogno, 2015, p. 108, translated from Spanish).

As Melogno points out on two occasions (2013a, 2013b), Kuhn himself did not support a dogmatic education. Nevertheless, in the last text we explored (2015), he did point out that Kuhn's philosophical categories of scientific revolutions, like normal science and incommensurability, could carry the interpretation of dogmatism in science activity. Even so, the way Melogno solves this contradiction is not by closing the door on a Kuhnian non-dogmatic education. However, he did say that finding the right conceptual conditions in which such a dogmatic consequence will not follow is challenging. Melogno finishes his text without explaining in detail what conceptual conditions he meant or how we could separate one part of Kuhn's philosophy (like normal science) from his science education to sustain a non-dogmatic view. Nonetheless, he still succeeds in explaining the main reasons we must abandon the simplistic view of a dogmatic education in Kuhn.

4. Conclusions

Melogno's views on Kuhn and science education have been more than just a stable and calm relationship. It started with a strong defense of Kuhn's philosophy and education, but in his last paper, it headed to a point where Melogno not only criticized Kuhn but also joined forces with other critics, such as Fuller. One thing that remained substantially unchanged throughout the developments we observed was Melogno's view on science education. His readings of Kuhn not only guided his career, but they also left a strong mark on his position on science education. Melogno advocated for a science education based on a holistic view of the history of science, where there should not be such a thing as a total rupture of paradigms, but one driven towards critical thinking. Melogno believes that science education should give students not only what they need to do science, if they want to do it someday, but also prepare them to discuss science, criticize it, and think about science both from inside and outside normal science. Melogno reminds us that science influences and is influenced by extra-scientific factors, like big companies and the military

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industry. As such, it cannot be isolated from criticism, even if the scientific community wanted it to be. Moreover, Melogno (2013a) says that science has values that support the critical formation of students. As supported by these epistemic factors, any science education that rejects them, or that does not acknowledge them, would not be scientific, even from a historical perspective of science where objectivity has been valued (Daston, 2007). From the standpoint of Melogno's argument for a partial rupture of paradigms, we could say that scientific values allow us to make stronger connections and avoid total ruptures.

This last paragraph leads us to suggestions for future research on Melogno's work. We start by recalling the paper "Algunas consideraciones acerca del sentido de la enseñanza de Historia de la Ciencia y Epistemología en la formación científica*"* (2004), which we did not include here. Future research could include that paper to explore whether we could identify two or more stages of Melogno's maturity on the subject of education. A second suggestion would involve examining scientific values and science education. New research could investigate whether and how Melogno's work and his defense of partial ruptures relate to scientific values, fostering a better historical perspective and critical thinking.

In conclusion, this paper was submitted shortly after the first anniversary of Melogno's passing. It is important to note that he not only followed in Kuhn's footsteps but also reinterpreted and analyzed them in his own way, leaving his unique imprint on the field of philosophy

Acknowledgement: A short version of this paper was presented at CLMPST-2023. In addition, it is important to express my gratitude not only to the reviewers who helped me improve this paper but also to Pablo Melogno for his kind, intelligent, and eternal moments of philosophical exchanges, sincere friendship, and inestimable lessons on how to be a good human being. I would also like to thank Carolina Sanchez for her help with this paper. Additionally, I am grateful to Samuel Odutayo for his indispensable help in reviewing this paper after its acceptance. Lastly, I would like to thank the organizers of this volume for their work in making this philosophically valuable project possible, and for their kind act of friendship in honor of Pablo Melogno.

https://doi.org/10.17533/udea.ef.356242

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