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Michel Foucault and the Historiography of Science

“The Use of Pleasure” of learning: A Foucauldian Perspective on the Role of Scientific Pedagogy in the Historiography of Science

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Abstract:

In this article, we present the work of the French thinker Michel Foucault, which, it can be argued, is centred on the Subject as a guiding concept and is divided into three perspectives of this concept, or axes of analysis, which also constitute crude markers of a diachronic evolution of Foucault’s thought: the archaeological (being-knowledge), the genealogical (being-power) and the ethical (being-with-oneself). Among these three axes, the first is more strongly linked to the study of science and is associated with the historical epistemology of Bachelard and Canguilhem. However, we present some recent works by historians of science who have taken scientific pedagogy as an object, making the second axis of analysis the starting point for a theoretical model of this domain of scientific practice in history. Finally, we promote a potential complementation of this model by including elements of the third axis of analysis, which these other authors do not discuss.

Keywords: Historiography; History of Science; Michel Foucault; Scientific Pedagogy; Subjectification

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The Three Axes of Foucault’s Work

Michel Foucault, a French intellectual (he disapproved of the identification with the disciplines with which he is usually associated, among them philosophy), is associated with a vast and original work within the Humanities. It is usually classified into three major periods – the archaeological, the genealogical and the ethical. Although this is the most common classification of the phases of Foucault’s work, there are alternatives, such as that of Veiga-

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Neto, who identifies the centrality of the Subject as a guiding concept for Foucault, and thus cuts out the phases in being-knowledge, being-power and being-with-oneself³ (Veiga-Neto 2014). Hacking (2002a, 2002b) also identifies the three axes and makes them the basis of his “Historical Ontology”, which seeks to investigate the historical becoming of a set of objects (what he calls “dynamic nominalism”) determined by at what degree they can be analysed from the perspective of these three axes (which excludes most objects from the natural sciences, but includes important objects from the human sciences, such as neuro divergences or the concept of child development).

Among these phases, it is in the first one that closely follows Georges Canguilhem’s school of epistemology, which in turn is influenced by Gaston Bachelard’s⁴ historical epistemology, that Foucault’s most evident contributions to the historiography and philosophy of science are usually identified. In this phase, Foucault seeks to demonstrate how a concept of great philosophical, especially ontological, importance (the “madman”, or “Man”) emerges historically from precise scientific delimitations that emerge in discontinuous steps over time.⁵ His works from that time, “History of Madness” and especially “The Order of Things”, are histories of science with embedded philosophical theses (Foucault 2013, 2012b).

Archaeology is the method with which he constructs these histories. It starts from the presupposition that the history of thought is, in analogy to Geology, marked by different strata of mentalities, worldviews, and ways of thinking (which he calls *episteme*) that periodise it and that precondition the form of the sciences produced in each of these periods.⁶ Hence, the activity of historicising the sciences at this level is analogous to the archaeological task of “excavating” those structurants of thought that mark and periodise a past era.

When one period gives way to another, that is, when one *episteme* gives way to another, much like in the metaphor of geological strata, this change is abrupt, heterogeneous, and discontinuous. The causes of these changes and why they operate in such a way that a certain *episteme* gives rise to a certain other (that of the classical period, which engendered Linnaeus’ taxonomy and Lamarck’s theories in biology, gives way to the modern period, which engenders Darwin’s theory of evolution) are not explored in detail.

Archaeology constituted an interesting possibility for the history of science, insofar as it provided a methodological option that moved away from biography or scientific hagiography, while also avoiding more vicious versions of the internalist historiography of the sciences (such as the circular “self-generation” of theories and ideas). This project also avoids the “social” causes and explanations for scientific creation and change from externalist historiography of the sciences, finding in a relatively autonomous object from the

³ The existence of a “pre-archaeological”, more existential and phenomenological phase of Foucault can be argued, in which he suggests, based on his studies of psychiatry and psychology and his experience as a visitor in psychiatric hospitals, a first analysis of the “madman” as a “lived experience” in the first edition of “Mental Illness and Psychology”, which would be replaced by the archaeological analysis of “History of Madness” (Foucault 2008, 2013; Oksala 2012c, 2012e). This transition becomes clearer when we study Foucault’s essays on language after his archaeological turn - he finds the freedom and limit-experience of existence sought by existentialists in the creative force of language as an entity which is autonomous from the human subject (Foucault 1998, 1986c; Oksala 2012d).

⁴ For a disambiguation of the multiple meanings of “historical epistemology”, and in particular the one that should be associated with Bachelard, and in part with Canguilhem, see Gingras, 2010 and Hacking, 2002b.

⁵ The emphasis on historical discontinuity is a legacy of Bachelard, and a sympathy with the historiographical movement of the *Annales*.

⁶ We could also think of the psychoanalytic metaphor (which in turn can be thought of as a geological metaphor in itself) of the *episteme* as the “unconscious” of epistemology, the *id* of the epistemological ego.

“superficial” domain of the scientist, his ideas, and even his society, the methodological principle of an investigation in the history of sciences. It is the *episteme*, which is a structurant of the “collective” thought of a time (Foucault 2012b, 2012a). More contemporary proposals for the diachronic analysis of thought with some similarity to archeology are Ian Hacking’s “styles of reasoning” (Hacking 1992).

Foucault’s interest in scientific discourse and its dynamics of making objects and corpora of knowledge remains in its next phase, the genealogical one. Inspired by Nietzsche’s work (Nietzsche 2013), he guides his historiographical methodology towards, not the way in which an abstract structurant of the knowledge of an epoch give rise to sciences, theories and objects of knowledge, but how the sciences, journalistic texts, moral pamphlets – what he collectively calls *discourses*⁷ – give rise to systems of knowledge-power that, through practices defined by them, create the conditions of existence of certain *subjects*, which can be strongly fixed in the imaginary and materiality of society through the institutionalisation of such practices⁸ (Oksala 2012a).

Interest in the sciences remains, but now less in terms of the historical development of the content of this knowledge (which distances genealogy from a stricter disciplinary identification with the history of science), but rather in how this knowledge expresses rationalities that produce and inform practices of social control that distinguishes modernity: that is, these are “histories of the present”.⁹

The important works of the period are “Discipline and Punish” and the “History of Sexuality 1” (Foucault 2012c, 1990). In “Discipline and Punish”, it is the mutual engendering of the sciences of criminology and psychiatry, intertwined from the turn of the 18th to the 19th century, with the practices of watchfulness and systematisation of prison life that, by virtue of the new idea of “reform” of the one who breaks the law, creates a new type of Subject, “the one who is reformed” through the scientifically and technically informed practices of internment.

The paradigm of this technique and this practice is the Panopticon, the ideal prison imagined by the jurist Jeremy Bentham in which all the cells are visible from the perspective of an unknown point of view that may or may not be occupied by a watchman. Thus, the one watched over internalises the power of watchfulness over himself and his peers when in this system. Despite focusing on the prison, the internalisation of watchfulness suggested by the Panopticon metaphor discussed by Foucault would be disseminated in all eminently modern institutions, such as the school.

Some consider a weakness of the genealogical Foucault to lack an explanation of why individuals would voluntarily submit to these situations of control; we will explore this topic

⁷ The historian of science Peter Galison argues that there is still an element of abstraction, non-materiality, in the notion of discourse, which would combine an initially positivist methodology (visiting an archive, reading the documents) with a structuralist turn (identifying the pattern and laws of combination of these texts), which seems to sustain some continuity with the notion of *episteme* (Galison and Packer 2016).

⁸ Corroborating a “continuist” perspective of Foucauldian work, in which the subject is the guiding concept, analysed in different ways, we note that the sciences that take subjects as their object (and construct them) are only possible in the 19th century, after the invention of the transcendental subject of Kantian philosophy at the end of the 18th century, the object to which the final analysis of “The Order of Things” is dedicated.

⁹ Despite constituting diachronic narratives about the constitution of practices and knowledge in the past, their intention as a literary and scientific genre is to disarm philosophical pretensions and theses that concern the present, such as the notion of *progress* or *humanism*. Thus, it is a presentist temporal regime that determines the investment of scientific work in the production of these stories and not some preoccupation more eminently derived from the past (although it is debatable how much this is not more common in the more usual historiographical genres: see Chang, 2021).

and where to find analytical support in Foucault’s work to look for answers to this question throughout the article.

In the “History of Sexuality”, Foucault identifies in the multiplicity of discourses, in particular scientific (psychoanalytic, physiological and psychiatric), about sex in the Victorian era, not a sign of a period marked by repression of sex and sexuality (like the era of “free love” of the 1960s and 1970s would characterise it), but of the production of modern notions of sex and sexuality that the present still makes use of (this not exclusively repressive character of power when understood as part of a knowledge-power binomial is one of Foucault’s most important contributions, and will be taken up again in the article). The person who performs sexual acts becomes, in medical language, a subject with sexuality that needs to be patched up, studied, classified, discovered by a scientific practice and theory and corrected by a legal practice and theory.¹⁰ It is in the explanation of the method in this work that Foucault clearly establishes his theory of power, half of the knowledge-power binomial:

[...] power is exercised from innumerable points, in the interplay of nonegalitarian and mobile relations. [...] relations of power are not in superstructural positions, with merely a role of prohibition or accompaniment; they have a directly productive role [...] there is no binary and all-encompassing opposition between rulers and ruled at the root of power relations [...] Power relations are both intentional and nonsubjective. [...] Where there is power, there is resistance [...] by definition, they can only exist in the strategic field of power relations [...]. (Foucault 1990, 94–96)

Unlike most usual Marxist and liberal conceptions of power and domination, for Foucault, neither power can be taken as a “substance”, a “legal currency”, nor is domination established in an absolute binary of dominant and dominated determined by socioeconomic conditions (the “class struggle”). Instead, the superstructure needs to be replaced by a microphysics of power: this is like an “elastic mesh” whose limits are defined by the knowledge-power devices, especially the institutionalised ones. The subjects are arranged in different n-ary configurations (the family, work, institutions), “deforming” this mesh with different intensities and for different durations of time, depending on how “crystallised” by society a particular practice or social configuration is.

Thus, two types of power relations are roughly distinguished: strategies between individuals and states of domination (Foucault 1988). In the first, individuals seek to lead each other’s actions toward a certain common or selfish objective in a relatively harmless way: Foucault’s example is a teacher guiding his student to take certain attitudes that lead to his school success. It is in this type of power relationship in which the relative position of the subjects in it is more fluid. In the second, the relative positions of the individuals involved in the relationship are quite fixed, and there is very little room for changing the relative state of “deformation” of the power grid. This would be the type of relationship established between individuals of different social classes. It is important to emphasise that the nature of the established power relations configures a gradation between strategic relations and states of domination, which is consistent with the conceptual principles cited above.

And it is in the third axis, related to the third phase of Foucault’s work, that the theme of the individual’s agency in the subjectivation process will be explored, engendered by the devices of knowledge-power and modulated by the strategies of power and by the states of domination. And it is again in a genealogy that Foucault finds the leverage point from which

¹⁰ In psychoanalysis, it is the subject himself who has the truth of his sexuality revealed through the psychoanalytic “confession”, and cured through his own speech, the enunciation of his own discourse.

to conduct his analysis of the subject: in this case, that of a comparative analysis of Christian and Greco-Roman morals and ethics (Foucault 1985a, 1985b):

“Up to that point, I had conceived the problem of the relationship between the subject and the games of truth in either of coercitive practices – such as those of psychiatry or the prison system – or of theoretical or scientific games – such as the analysis of wealth, of language, and of living beings. In my lectures at the Collège de France, I tried to grasp it in terms of what may be called a practice of the self [...]. In the Greek and Roman civilisations, such practices of the self were much more important and especially more autonomous than they were later, after they were taken over to a certain extent by religious, pedagogical, medical or psychiatric institutions.” (Foucault 1988, 281-282).

Foucault distinguishes between two types of morality – that provided by a code of conduct, and the practice originated from the relationship of individuals with the code – and he also distinguishes both from a notion of ethics – identified, for example, in the “Alcibiades”, of Plato – as the forms and techniques through which an individual mould oneself into a moral subject, that is, a subject of morality (Oksala 2012b).

Foucault draws attention to the fact that Christian morality, the one that most informs our culture, emphasises the code – the moral norms of Christianity are multiple and designed for each possible situation – making Christian ethics one of strict obedience to the code. In the previous Greco-Roman culture, the code was much simpler and assumed, in the moral practice of the individual, the role of general orientation, with practical morality being more important, achieved by an ethics that corresponds to a creative activity, a “technique of the self” focused on a morality “founded on a personal choice to live a beautiful life and to leave to others memories of a beautiful existence.” (Oksala 2012b).

Foucault again focused on presentist concerns, identifies in this morality, and in the conduction of “techniques of the self” that constitute Greco-Roman ethics (adequately appropriated for contemporary society, not in themselves – Foucault is neither a nostalgic nor an anachronistic), an alternative to our society, which he sees as obsessed with the regimes of scientific truth and the governability of large population contingents that he saw as capable of causing the intoxication of power relations. These power relations, however, as his previous work points out, are irreducible:

I do not think that a society can exist without power relations, if by that one means the strategies by which individuals try to direct and control the conduct of others. The problem is not of trying to dissolve them in the utopia of a perfectly transparent communication, but to give one’s self the rules of law, the techniques of management, and also the ethics, the ethos, the practice of self, which would allow these games of power to be played with the minimum of domination. (Foucault 1988, 298)

Self-government, therefore, would distance itself from the instances of the power-knowledge characteristic of modernity, adopting more the *éthos* of the individual, making his life a work of art – an *aesthetics of existence*. The individual finally assumes, in Foucauldian work, agency over the process in which he is subjectified.

The “Foucauldian” approach in the History of Science Pedagogy

It’s been just a few decades since historians, sociologists and anthropologists of the sciences (often grouped together as scholars of *science studies*) turned more seriously, albeit very timidly in terms of the amount of work developed, to studies that evidence the role of

scientific pedagogy in the concerning problems characteristic of the investigation of scientific culture – such as the constitution of properly scientific practices, the circulation of knowledge and scientific materiality, and the nature of innovation in the sciences. Although some of those who have been appropriated as founders of this interdisciplinary trend, such as Thomas Kuhn, have taken the issue of scientific training as central (Kaiser 2005a). Among these, there are some already “classic” studies that, following the “tradition” of science studies, generally end up involving case studies of scientific training practices *in loci* that are very temporally and geographically located (Kaiser 2005b; Olesko 1991; Rudolph 2002; Warwick 2003).

Although the localised study is commendable in historiographical and sociological research, allowing empirical studies to guide researchers’ conclusions about the problem in question, it would be important for the development of works with more ambitious aspirations to discuss possible broader philosophical or sociological models that support and guide research beyond a microhistorical “archive fetish” (Galison 2008; Secord 2004). Some, such as Massimiliano Badino and Jaumes Navarro, argue that an epistemology of science relevant to the history of science can be centred on the role of the pedagogical domain in the scientific enterprise (Badino and Navarro 2013). David Kaiser and Andrew Warwick, two important authors in this line of studies, sought to outline an epistemology of the type, called “Foukuhnian”, for being inspired by both the work of Thomas Kuhn and Michel Foucault (Kaiser and Warwick 2005).

Turning to Kuhn, the authors believe in recovering the initial meaning of the widespread and controversial concept of “paradigm”, which would be an abstraction elaborated from a turn operated by Kuhn in the understanding of what would be the process of “learning” in the natural sciences (in particular in physics, it is important to emphasise, the author’s mother discipline) in two movements. First, he recognises that the process is quite authoritarian and dogmatic, leaving no space for the student to question the accepted methods and theories, which are presented in this tone in textbooks and manuals. He then identifies that, rather than the student “learning” science through the process of mastering the key concepts of a discipline or the principles of a theory, which make up the “bulk” of text in textbooks, he is in fact “trained” to solve a limited number of problems of well-known solution through the use of a theory and a certain set of concepts (in the most contemporary philosophy of science literature, we would say that Kuhn refers to the most successful models of a certain theory¹¹) and to learn to identify the same problem already solved in new problems, or to develop techniques that reduce or simplify the problem to already known cases. Scientific pedagogy would be, therefore, a kind of training aimed at engaging its subjects with the “puzzle-solving” activities that characterise “normal science” (Kuhn 1996, 2011)

The limitations the authors identify in the Kuhnian model of the role of pedagogy in the development and reproduction of scientific knowledge are essentially its ahistorical character – Kuhn’s account, especially in the *Structure of Scientific Revolutions*, and especially because of its more structuralist character, seems to suggest that the forms of scientific training in Kuhn’s present are a priori essential and reproduced in scientific history since its birth – and the mechanisms through which the training is successful, in addition to the already classic problem (which gives rise to his thesis of incommensurability) of how innovation is possible within such a narrow regime of reproduction:

¹¹ See, for example, Cartwright, 1999.

In essence, he assumed that the distribution of canonical texts such as Newton’s *Principia* (or derivative textbooks) was sufficient to generate a community of practitioners engaged in a common project. He had very little to say regarding the role or form of the training regimes within which such texts and textbooks were employed. [...] On the one hand, he adduces the authoritative tone of such books when arguing for the dogmatic nature of scientific education; on the other hand, he claims that the formal explanations found in textbooks cannot teach students the very problem-solving skills he identifies as crucial to competent practice. [...] A much richer account of pedagogical resources used to train scientists and engineers is required if we are to provide a plausible account of the way training is generative of normal-science activity. (Kaiser and Warwick 2005, 396-397).

From Foucault, the authors highlight the concept of discipline, which, as we discussed, is characteristic of the author’s genealogical phase and used profusely in the work “Discipline and Punish” (Foucault 2012c), and the Foucauldian conception of power, in which it is disseminated throughout society, with its configuration determining and being determined, in a double operation, in numerous instances of dispute, being intertwined with ways of knowing and production of knowledge (Foucault 1990). It is in this sense that power is exercised in social devices such as prisons and, especially for Kaiser and Warwick, the school; it is with human and social knowledge (*savoir*) that the disciplinary regimes of these institutions are constituted – the spatial arrangement of study rooms, the timetable, physical reinforcement exercises, memorisation techniques, etc – which are actively carried out by the disciplined and produce a “positive” transformation (recall here the “productive” character of power for Foucault) in them as they become subjects capable of carrying out a series of tasks with a certain “effectiveness” by following this regime of discipline

The main disciplinary technology that shapes the student subject, for example, is the exam – through it the individual in the school institution is identified by the teacher in their relative strengths and weaknesses regarding the execution of a certain task, whose effective resolution sets the objective of the learning process, and can thus be shaped by this teacher through specific techniques that improve their performance in solving the task. According to the authors:

Where Kuhn’s account of pedagogy was confined to occasional and vague references to the contents of canonical treatises and textbooks, Foucault’s evoke a much richer and interactive nexus of institutionalised gazes, bodies, gestures, architectures, routines, incitements, examinations, and punishments. [...] In this sense Foucault points to a level of analysis at which it should be possible to historicise the processes by which specialised technical competencies became the common preserve of widely extended communities of practitioners – the phenomenon Kuhn referred to as normal science. (Kaiser and Warwick 2005, 402-403).

And here, Foucault’s historicity has a great advantage over Kuhn’s structuralism, insofar as we turn to the problem of how, in the last two hundred years, the conceptual, but especially technical, leap in the scientific disciplines that allowed, according to an example of the authors, for the General Theory of Relativity to be mastered and applied to problems of astronomy in the period of a decade, while the Copernican Heliocentrism took at least a hundred years to be completely mastered by the scholars of the mathematical sciences. It is at the turn of the 18th to the 19th century, according to Foucauldian periodisation, that the disciplinary techniques are invented and iteratively applied by the new human sciences to individuals who integrate modern institutions, such as schools. The growing subjectification of the individual as a subject of learning – a subject disciplined for learning – could explain

how much more “effective” scientific activity has become, especially with regard to the dissemination and circulation of knowledge.

The strengths of the “Foukuhnian” model for the history of science, and for the history of pedagogical practices in the sciences are summarised by the authors as follows:

[...] in order to historicise training’s place in the sciences we need to transcend Kuhn’s idealistic, global, static, and cyclic model of scientific change. We have suggested that this can be accomplished in two stages: first by noting the compatibility of Kuhn’s emphasis on skill acquisition with Foucault’s insight that power in the form of social relations does not inhibit or conceal knowledge but is necessary to its production; and second, by building on Foucault’s claim that the minutiae of everyday training practices have the power to generate new capabilities in human beings, thereby bringing about significant historical change. (Kaiser and Warwick, 2005, 406)

We can notice echoes of an epistemology with these characteristics in works by these two authors, both immediately before and after this text. In “Drawing Theories Apart”, Kaiser investigates how different research traditions, geographically distant, appropriated and made use of Feynman’s newly discovered calculation devices for the discipline of High Energy Physics in the immediate post-war period – the diagrams that were named after him – effectively transforming it through this process of circulation between sub-disciplines and departments strongly modulated by their pedagogical tradition (Kaiser 2005a).

In “How the Hippies Saved Physics”, the same author demonstrates that material changes in the characteristics of graduate studies in North American physics throughout the 1950s – greater investment and programs to encourage enrollment in higher and graduate education – generated an unprecedented demand for disciplines involving advanced topics of Quantum Mechanics, and shaped the way this physics was taught and how its textbooks were written (in the content selection, for example), emphasising, in this case, mathematical techniques of problem-solving rather than conceptual clarification – something that was seen as a fundamental part of the discipline until that moment, due to the role that conceptual and interpretive debates played throughout the construction of the theory (Kaiser 2011).

In these two examples, we can identify an emphasis on how pedagogical techniques generate change in the content or even in the disciplinary emphases and boundaries of a science – this is a point of interest that Kaiser and Warwick accuse Foucault of not exploring with due attention:

What is particularly important here, though Foucault had little to say on the matter with respect to training, is that pedagogical reorganisation on the scale he envisage could, over time, have profound effects on the field itself. (KAISER & Warwick 2005, 400)

Warwick seeks to explore this point in “Masters of Theory”, where he investigates the institutionalisation of very particular ways of training students in Mathematical Physics throughout the 19th century in England, specifically in Cambridge, and how this shaped the very contents of the discipline of mathematical physics – in particular, the Electrodynamics of Maxwell, Larmor, Fitzgerald, etc. – and influenced the ways in which the Theory of Relativity was appropriated by these English mathematicians (Warwick 2003). He explores the coaching mechanisms, – Cambridge coaches – evaluation techniques, – the *Tripes*, around which the coaching mechanism was established – and regimes of the discipline of the body and mind of students – the cultivation of physical and mental health, of an ideal of masculinity through the practice of canoeing, and of cognitive reinforcement through the mental exercise of solving differential equations with varying degrees of difficulty.

However, both Warwick and Kaiser see a limitation in the Foucauldian legacy of the epistemology that they propose when considering the element of the individual’s volition when engaging with pedagogical practices in the sciences that are so intense and invasive:

Despite his claim that training can find and exploit new capacities in those subjected to its rigours, it is invariably the teacher who is the ‘knower’ while the student remains the ‘known’. Yet the purpose of technical training is not just to manipulate the student’s behaviour for the purposes of the master, but to reproduce the master’s skills in the student. For this process to work effectively the student must *want* to acquire the master’s knowledge and be a willing and active participant in his or her own education. (Kaiser and Warwick 2005, 404)¹²

The solution proposed by the authors is a localised investigation, in time and space, of the reasons for individuals to be subject to these regimes¹³. To us, however, this solution seems to compromise too much the ambition of an epistemology, or even a theoretical model for the history of science, that strongly links the content and forms of the sciences with pedagogical practices. We believe that in Foucault himself, but not now through the genealogical axis, through which the concept and studies of the discipline are constructed and analysed, but through the ethical axis, the “Foukuhnian” epistemology can be adequately complemented.

Complementing the “Foukuhnian” Approach: The Ethical Axis, or the “Being-with-oneself”

As anticipated, we believe that Kaiser and Warwick’s exposition of their Foukuhnian epistemology is very rich for the historiography of science, but we also believe that some of the problems they point out, in particular regarding apparent limitations of the “Foucauldian side” of the approach, can be solved without referring to intellectual elements external to the references used. In particular, that Foucauldian work, in its ethical variety, can point to a solution to these “blind spots”.

Let us begin by recalling and emphasising the elements of Foucault’s Work that we believe have been ignored in Kaiser and Warwick’s bibliographic synthesis:

While Foucault had insisted that resistance was always inherent in power as its irreducible counterpart, his account nevertheless left it open for the most part how, by what concrete means, subjects should form and instigate resistance. (Oksala 2012b)

In other words, we have to admit from the outset that Foucault’s work, even in its genealogical and disciplinary phase, the one exclusively explored by the authors according

¹² The terminology used by the authors in the highlighted passage seems to suggest, despite the fact that there is no direct citation of the work “Pedagogy of the Oppressed” or equivalent in the original text, a Freirean critique of the perspective very marked by the authoritarianism of the Foucauldian reading of the educational process in “Discipline and Punish”. We leave open this potential path of theoretical complementation.

¹³ Kaiser, for example, explores the case of what he identifies as the typical American physicist of the first two decades following the post-war period - an ambitious young man who aspires to reach the middle class of *Cadillacs* and suburbs, constructing his identity through the media focused on this social segment. The science stimulus packages of those decades allowed the physicist career to be seen as a means to the realisation of these ambitions - much more than, what was more common before, and would become again from the 1970s and 1980s, a means for the realisation of more “purely” intellectual ambitions (Kaiser 2004).

to the above exposition of Foucaultian epistemology, opens a space of reflection toward the nature and possibility conditions of resistance to disciplinary power. Of course, the Foucauldian theory of power includes in its own structure the possibility of agency from the part of disciplined elements through practices of resistance. It is important, nonetheless, to complement the required analysis of the disciplinary regimes, for it does not explain how these resistances would occur. As indicated by the authors, that would require a specific empirical study.

Thus, we must refer more directly to Foucault’s later work, notably in the *History of Sexuality*, 2 and 3 (Foucault 1986a, 1986b), which, we argue, suggests not only the form taken by practices of resistance, but indeed suggests, more radically, an “appropriation” of the disciplinary order by the disciplined subject for the production of an “aesthetics of existence”, which he identifies as the *éthos* of Greco-Roman ethics in his historical study, which would consist of a “practice of freedom” on the part of the disciplined. In an interview collected in a volume by Paul Rabinow, Foucault expresses this idea:

I have always been suspicious of the notion of liberation, because if it is not taken with precautions and within certain limits, one runs the risk of falling back on the idea that there exists a human nature or base that, as a consequence of certain historical, economic, and social processes, has been concealed, alienated or imprisoned in and by mechanisms of repression. According to this hypothesis, all that is required is to break these repressive deadlocks and man will be reconciled with himself. [...] This practice of liberation is not in itself sufficient to define the practices of freedom that will still be needed if this people, this society, and these individuals are to be able to define admissible and acceptable forms of existence or political society. [...] This is precisely the problem I encountered with regards to sexuality [...] This ethical problem of the definition of the practices of freedom, it seems to me, is much more important than the rather repetitive affirmation that sexuality or desire must be liberated. (Foucault 1988, 282-283)

10

From this reaffirmation of the themes present in the first volume of the “History of Sexuality”, and also to a somewhat more rudimentary degree in “Discipline and Punish”, regarding the productive nature of power and regimes of discipline, and their inescapable nature, which seriously hinders dreams of some “liberation” utopia – a popular point of view in the 1970s – but with a fresh perspective informed by the broad historical study of Greco-Roman ethics, he goes on:

Freedom is the ontological condition of ethics. But ethics is the considered form that freedom takes when it is informed by reflection. [...] In the Greco-Roman world, the care of the self was the mode in which individual freedom – or civic liberty, up to a point – was reflected [*se réfléchir*] as an ethics. [...] What we have here is an entire ethics revolving around the care of the self; this is what gives ancient ethics its particular form. I am not saying that ethics is synonymous with the care of the self, but that, in Antiquity, ethics as the conscious practice of freedom has revolved around this fundamental imperative: ‘Take care of yourself’ [*soucie-toi de toi-même*]. (Foucault 1988, 284-285)

The “care of the self” would consist of a set of techniques, usually involving some form of asceticism, employed by an individual to control his passions and will in a way that they do not control him. In other words, so that the demands of the body and of the will do not deprive the individual of his freedom, he needs to actively engage in practices that curb them: effectively, “practices of freedom”. The way in which these practices lead to an ethical stance towards others is explored by Foucault below:

What makes it ethical for the Greeks is not that it is care for others. The care of the self is ethical in itself; but it implies complex relationships with others insofar as this *éthos* of freedom is also a way of caring for others. (Foucault 1988, 287)

[...] the risk of dominating others and exercising a tyrannical power over them arises precisely only when one has not taken care of the self and has become the slave of one's desires. But if you take proper care of yourself, that is, if you know ontologically what you are, if you know what you are capable of, if you know what it means for you to be a citizen of a city, to be the master of a household in an *oikos*, if you know what things you should and should not fear, if you know what you can reasonably hope for and, on the other hand, what things should not matter to you, if you know, finally, that you should not be afraid of death – if you know all this, you cannot abuse your power over others. (Foucault 1988, 288)

The following passage refers almost directly to the previous quote from the work of Kaiser and Warwick where they question the need of a bidirectional relationship between master and apprentice for the scientific training process to take place:

Éthos also implies a relationship with others, insofar as the care of the self enables one to occupy his rightful position in the city, the community, for interpersonal relationships, whether as a magistrate or a friend. And the care of the self also implies a relationship with the other insofar as proper care of the self requires listening to the lessons of a master. One needs a guide, a counsellor, a friend, someone who will be truthful with you. Thus the problem of relationships with others is present throughout the development of the care of the self. (Foucault 1988, 287)

11

We see here why Foucault was captivated by this perspective: we have here a conception of ethics that readily admits the existence of irreducible power relations in society, and that, from this recognition, takes as a necessary effect of this irreducible fact an *éthos* attuned to avoiding the constitution of states of domination (tyrannical power, in a more Greco-Roman language) – those that Foucault identified as the toxic distortions of healthy power relations.

Foucault, then, gets to the point that interests us – and also him – the most, which is how we can relate this historical study of ethics in Antiquity with the genealogies of institutions, governability and discipline in Modernity:

I would say that if I am now interested in how the subject constitutes itself in an active fashion through practices of the self, these practices are nevertheless not something invented by the individual himself. They are models that he finds in his culture and are proposed, suggested, imposed upon him by his culture, his society, and his social group. (Foucault 1988, 291)

Thus, we find the connection between the techniques and regimes of the body and mind presented by Modernity and Greco-Roman ethics. There is the possibility of appropriating the disciplinary techniques that are cast upon us in modern society in order for us to perform certain tasks effectively if we take them as techniques of ourselves aiming at “self-care”, if they help us to subjectify ourselves to a certain extent as ethical subjects.

We will conclude the argument by presenting an interpretation of the history presented by Andrew Warwick in his “Masters of Theory” in which, in addition to the interpretation of the techniques of pedagogy in Cambridge as a disciplinary regime, we take students as engaged in practices of “self-care”.

Warwick narrates the constitution process of the mathematics teaching in the very specific flavour of Cambridge University in the 19th century through the constitution of the practice of coaching and the organisation of graduation exams known as *Tripes*, through which students were ranked; the best-ranked students applied for positions as lecturers at the university or themselves worked as coaches for the exam. The centrality of teaching mathematics to the university was designed by figures such as William Whewell, who took the discipline as central to the rational and moral development of the English citizen, who would rise high in the hierarchy of that society, and William Hopkins, who valued the more competitive and aggressive aspects that emerge in the context of a ranking high-level physics-mathematics exam.

Whewell valued mathematics (and specifically Newtonian dynamics) for the self-evident truth of its premises and the absolute certainty of its conclusions. Its study would have no other effect on those who submitted to it than to make them respectable citizens aware of their role in society, fair and rational in their decisions and, therefore, moral. Hopkins emphasised the mystical-transcendental aspect of Mathematics as an element of the divine, not human, creation, and thus the exhaustive study of it would indicate a greater fear of the moral law and God. The most fearful student would then be the most studious and devoted, which would also serve the objective of ranking well in competitive exams, making religious zeal and competitiveness strongly related in this perspective of mathematical study. It is this competitive aspect that most profoundly marked the university environment throughout the 19th and part of the 20th centuries¹⁴.

At the same time, it was during the 19th century that the “analytical reform” took place in the teaching of British mathematical physics. The emphasis on the geometric interpretation of the problems of differential and integral calculus, and the formulation of differential equations from primitive “concrete” concepts, such as the notion of Newtonian force, which was equated with the intuitive notion of “muscle effort”, were replaced by the introduction of more sophisticated methods of solving differential equations from the Continent. The connection of the abstractions of mathematical physics with the concrete world through concepts such as force were progressively replaced by the more abstract notions of energy and “Lagrangian” or “Hamiltonian” functions. The Whewell school of thought was particularly attached to the more traditional forms of the discipline rather than the continental sophistications and abstractions, which contributed for it being seconded by the Hopkins approach to mathematical study.

Important figures in the history of mathematics, such as Francis Galton, Karl Pearson, James Clerk Maxwell, and William Thomson (Lord Kelvin), not to mention many other “invisible” ones, passed these exams, and Warwick recovers frightening accounts of their experiences with them:

Galton was initially exhilarated by the intellectual adventure and sheer pace of Hopkin’s coaching sessions [...]. A few weeks into his third year, Galton’s health began to fail completely [...] the three best mathematicians in the college in the year above him were all graduating as poll men because their health had broken down under the pressure of hard study. [...] Galton concluded that the unremitting emphasis on

¹⁴ This process takes place in a period of dispute and reform in English society, in which one of the battlefronts is the education system, between the radical and the conservative wing of Parliament. Whewell sided with the Conservatives, and his model of the British citizen sought to restore or sustain the values of an Anglicanism that was being challenged. Simultaneously to this dispute, it is at this moment that university education starts to be taken by young people from the middle classes with good school performance as a perspective of social growth within the rigid hierarchy of British society.

competition in Cambridge undergraduate studies was in desperate need of reform [...] He subsequently suffered a complete mental breakdown and had to leave Cambridge for a term. (Warwick, 2003, 183)

The two most outstanding mathematical physicists produced by Cambridge in the mid-nineteenth century, William Thomson (later Lord Kelvin) and James Clerk Maxwell, were similarly disaffected by their undergraduate experience. More than nine months before he sat the Tripos examination of 1885, the extraordinarily able and energetic Thomson informed his father that ‘three years of Cambridge drilling is quite enough for anybody’. During the equivalent year of Maxwell’s undergraduate career, 1853, he was taken ill while working ‘at high pressure’ for the Trinity College summer-term examinations. [...] During the first two years at Cambridge, Maxwell had resisted pressure to concentrate solely on preparations for the Mathematical Tripos and had continued to read and discuss literature and philosophy. Upon his return to Cambridge, the still weakened Maxwell abandoned all but his mathematical studies, doing only what ‘Hopkin’s prescribe[d] to be done, and avoiding anything more’. (Warwick 2003, 185-186)

Having recovered from the sources these frightening accounts of the mental stress to which undergraduate students were subjected, which seems to justify Warwick’s own theoretical concern in the 2005 chapter with Kaiser quoted above as to finding the reasons why individuals submitted to this discipline in the first place, he tries to indicate that, for the most promising students, throughout the 19th century, along with the very strict regime of the mind, a concern with the body was also developed, and an equally rigorous regime of the body:

[...] for some reasons, not entirely clear, the most ambitious undergraduates gradually transformed the traditional afternoon ramble or promenade into a daily regimen of measured physical exercise. This exercise became the recognised complement of hard study, and students experimented with different regimes of working, exercise, and sleeping until they found what they believed to be the most productive combination. As the Mathematical Tripos became yet more demanding and competitive through the 1820’s and the 1830’s, these regimes of exercise were transformed into a parallel culture of competitive sport. (Warwick 2003, 182)

One of these students was the renowned physicist James-Clerk Maxwell, who, on the eve of his exam, studied various combinations of study and physical exercise that would serve his objective of submitting to university discipline: “One daily routine working late at night and involved then taking half an hour’s vigorous physical exercise. [...] In the summer he exercised in the River Cam [...]” (Warwick 2003, 196).

William Thomson, another renowned physicist, also adapted the double ideal of masculinity that had been forming in Cambridge – of the man who strains himself equally to the limits of his physical and mental capacities – to his “regime of being”:

Already an accomplished mathematician when he arrived in Cambridge in 1841, Thomson was recognised from the start as a potentially outstanding scholar. His father, a mathematics professor in Glasgow, was soon troubled to learn that his son had bought a boat to row on the river Cam and was contemplating joining the college boat club. William quelled his father’s fears by pointing out that his coach, Hopkins, not only approved of rowing but actively recommended it as a means of exercise and diversion from study. By the end of his second term, Thomson claimed that his general health had been greatly improved by rowing, and that he could ‘read with much

greater vigour that [he] could when he had no exercise but walking.’ [...] By the 1860’s, rowing was described as a ‘mania’ in Cambridge which, together with cricket, shared the ‘honour’ of being the ‘finest physical exercise that a *hard reading* undergraduate can regularly take’. (Warwick 2003, 182)

We see here how the two greatest exponents of British Cambridge-style mathematical physics sought to constitute, on a personal level, regimes of control of their own body and mind to actively engage with an externally imposed regime of discipline – of the *Tripos* and of the coaching – given that they sought to become the type of professional objectified and valued by that institution. The British mathematical physicist, with a strong body and mind and resistant to the physical and mental hardships of earthly “hard work” to appreciate an object taken as a transcendent – mathematics. This would be the expression of a model for the Victorian moral subject, object of the individual’s self-subjectification, in this case through the regular study of mathematics.¹⁵

Warwick emphasises in the epilogue to his study how much this model of scientific pedagogy influenced the 20th century, and set the standard for productivity and progressive development of the discipline of mathematical physics since then. The success of the “analytic reform” is attributed in part to the pedagogical preconditions present in Great Britain, consisting of a productive effect of this disciplinary regime in an explicitly Foucauldian description.

Warwick’s work concludes by emphasising the relevance of scientific pedagogy as a historiographical object that allows an investigation in the *longue durée* of the cultural reproduction of science and a more empirical investigation of innovation in science, case by case, through the specific study of the pedagogical biography of an outstanding scientist (his example is the British physicist Paul Dirac). Science is a set of complex and diverse cultural practices, and an accumulated codex of knowledge as extensive as it is intensive, that understanding how it sustains itself and subsists, in its modern form, for more than three hundred years, is a problem in itself scientific.

We would then suggest that the theoretical fecundity of the pedagogical approach in the historiography of sciences can be complemented by the interpretation of the sources brought to light by Warwick according to Foucault’s ethical axis of analysis, revealing the physical and mental exercise practices of those engaged with the scientific training in the presented context.

The voluntary engagement of these individuals with the particularly dreadful regimes of discipline revealed in the sources through the practices described constitutes what Foucault called “care of the self”, because they are aimed at the personal control of passions and volitions that constitute an “aesthetic exercise” of existence itself, as it aims at the proud display of self-adjustment to the economy of values of a certain society, that is, the self-constitution of a moral subject.

Thus, we argue that as historians, we can always try to place the study of localised episodes of scientific pedagogy in a broader and more directed project in the *longue durée* of the constitution of scientific subjects and the cultural reproduction of science. If we are guided by the “Foucauldian” model, paying particular attention to two potential effects predicted by it in our historical sources, the productive effect of the specific disciplinary

¹⁵ We have already seen how there was a conflict among those who reformed the university over the way in which the teaching of mathematics would promote the Victorian moral subject. This notion of the subject itself was not unambiguous either, although a specific version emerged as the “victorious” one, and it is the one we described above, combining masculine ideals of physical and mental achievement. This ideal would change in the final decades of the 19th century, entering the 20th, with a distinction between the physical and the mental emerging, with a special emphasis on the first, and contempt for the second; however, this process does not interest us here.

regimes studied, and the forms of voluntary engagement assumed by historical agents as practices of the self.

Final Remarks

We began this article by presenting a panoramic view of Foucauldian work, adopting a classic periodisation of it, which is also an epistemic division: the archaeological, genealogical and ethical phase. We prefer the term “axis of analysis” to “phase” mainly because it evokes the epistemic rather than the chronological meaning of this division. We emphasise the importance that the first two axes – archaeological and genealogical – had, and still have, for the historiography of science, indicating that our interest is to enable the third axis of analysis, the ethical, as a tool for this historiography.

We did this by visiting historical studies focused on scientific pedagogy, each one in different times, places and regarding different disciplines, emphasising that two authors, David Kaiser and Andrew Warwick, identified in these studies the potential of a theoretical-epistemological background. This theoretical model revolves around two structuring notions derived from the work of two important names in the human sciences who were involved to some extent with the historiography of the sciences – Thomas Kuhn’s “paradigm” of the *Structure of Scientific Revolutions* and Foucault’s “discipline” of *Discipline and Punish* (ie, that of the genealogical axis).

We align ourselves with these authors, but we identify in their analysis of the Foucauldian work in what would be relevant to this project of a “Foukahnian” epistemology of the historiography of the sciences, a limitation by not emphasising, and even, at least in Kaiser and Warwick, disregard its ethical axis, since without it the analysis of the pedagogical process seems too authoritarian and unidirectional, which is unsatisfactory for the desired theoretical model (Kaiser and Warwick 2005).

Thus, we seek to identify in Warwick’s own work, “Masters of Theory”, in which the history of mathematical physics, and the production and reception of two of the most important physical theories in history – Classical Electrodynamics and the Theory of General Relativity – is told from a pedagogical point of view, delving into the history of the institutionalisation of mathematical physics in Great Britain, the modes of scientific training at the University of Cambridge, and the gestures of individual’s which reveal active alignment to the harsh academic discipline, a line of interpretation inspired by Foucauldian works identified with the ethical axis of analysis.

We identified in the gestures of the constitution of particular regimes of the body and mind to the rigours of the discipline an example of the practices of the self for moral subjectivation that are the object of this third Foucault. Thus, we argue that the complementation of the “Foukahnian” epistemology proposed by Kaiser and Warwick with a dimension of analysis of the gestures and attitudes taken by individuals to actively engage in academic discipline processes constitutes a good theoretical model for research work in history of science that investigate temporally and geographically localised cases of scientific learning processes, which may end up serving a more ambitious project of investigation of the conditions of cultural reproduction and scientific innovation in the *longue durée*.

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