Considerations on the Education of Prospective Scientists: The Learning Contract and the Social Curriculum

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Abstract

The present paper examines aspects of how students are incorporated in the community of mature scientists. Our goal is to illustrate how graduate students learn to distinguish correct procedures from incorrect procedures following two, sometimes contradictory, curricula: the explicit discourse of mathematics and physics on one hand, and a hidden curriculum learned during their enculturation (which we call the *social curriculum*).

We support our analysis in the observation of the occurrence of wrong mathematics in published scientific works (we offer two simple examples out of countless more than can be found).

The social curriculum naturally addresses matters concerning communication within scientists and the various forms of social recognition. However, emerging from social pressure, quality control of the scientific effort is frequently incorporated into the social curriculum ruling over, and sometimes against, the mastering of meta-cognitive knowledge and scientific rigour in which scientists are supposed to excel.

1 Introduction

A relevant part of the training of graduate students that will eventually become scientists consists in establishing new learning and working contracts.

Undergraduates develop along their studies the skills and knowledge described by the syllabus of the learning curriculum. After graduation, much of the curriculum becomes a contract, i.e., graduates are expected to show the skills and master the knowledge listed in the learning curriculum. We may call these conditions the *learning contract*. This contract consists among other things in mastering the incorporation of new knowledge and skills, and the ability of solving exercises in well-determined and controlled environments. However, the strategies to address new problems developed in undergraduate studies have to be transformed into different strategies under graduate studies, useful for addressing open problems in (quite often) fuzzy contexts.

More often than not, the change implies the renegotiation of the learning contract established as undergraduate, into a new contract. The successful undergraduate strategy of trying to reduce a new problem to a contextualised exercise (to be found in a book)[1] becomes insufficient for graduate studies. In fact, as a result of graduate studies, students are expected to enhance the learning contract, being able to handle open problems in weakly controlled environments with creativity and independence. A scientist is expected to be an expert in the discovery and incorporation of new knowledge and skillful in the use of the adequate strategies. She/He should be excellent in scientific self-control, and scientific rigour, in particular, she/he must excel in meta-cognition [4]. The enhanced learning contract is an attempt to enact the archaic ethic code of scientific practice, namely *the preservation, recombination, and development of knowledge, in devotion to the truth, especially the truth* [15]. This hagiographic view is in fact part of the syllabus and reflects how scientists like to regard themselves and their activity. The agreement on a new contract is normally

[1] In Theoretical Physics: "Teachers show students how to recognise that a new problem is like this or that familiar problem; in this introduction to the repertoire of soluble problems to be memorised, the student is taught not induction or deduction but analogic thinking." [19]

considered a milestone in the development of the Ph.D. work[2].

In parallel to the new curriculum directed towards developing the necessary mastering of "self-monitored learning" and beyond, students are incorporated to a "local group" [5] (which is shaped mostly by the senior scientists) as apprentices that share a common interest and interact in different forms such as scientific meetings and communications to a particular set of journals (in which the senior scientists of the group, reciprocally, review submitted communications). It is within this context that the meaning of "significant contribution" is established.

It has already been observed that the "local" group has little to do with geographical proximity. We use this concept aiming to describe a working community that shares goals, beliefs and practices. In simple words, an Asian mathematician shares much more understanding, language and practices (within mathematics) with a South-American mathematician than what she/he shares with an Asian chemist sitting next room to her/him. In other words, Ph.D. students follow also a curriculum with a social content.

Graduate students learn in an informal way the views of the scientific community they are entering, just by belonging to it, spending time with their advisor, other teachers and other students. We may call this learning process the *social curriculum*. This process has been studied under the name of enculturation [6, 14]. This social agenda is viewed as the practice of science tending to the realization of the archaic ethic code and in no case as a challenge or alternative to it.

The social curriculum does not reflect the official institutional view of how a sound scientist should work (as stated by the enhanced learning curriculum) but rather the unwritten rules establishing how scientists frequently *are*. Inasmuch these two things are different –as we claim them to be and show some examples in the coming Sections– the social curriculum acts *de facto* as a *hidden curriculum* [16].

The topics belonging to the learning and social curricula are not necessarily disjoint. Of particular interest for our study is the quality control, i.e., those parts of the curricula that address "correctness", i.e., the use of valid inductive and deductive reasoning. It can be argued that within mathematics and physics, the social curriculum does not influence correctness, since there is no such thing as "true by consensus" (a common expression among physicists is "we cannot take votes for or against Newton's law"). In other words, what is correct or not in physics or mathematics does not belong to any item of the social curriculum but rather it is a matter that will be subject to the syllabus written in the learning curriculum. One of the conclusions of the present work is that this is not the case. We will discuss below empirical evidence from physics supporting the idea that "correctness" belongs in both curricula. Moreover, social practices may interfere and overrun correctness rules as stated in the written syllabus of the learning curriculum.

Scientific publications are influenced by both curricula since on one hand they are expected to contain "correct", new and valuable research and simultaneously they are used as a measuring parameter within the scientific community.

[2]The distinction between curriculum and contract is arbitrary to some degree. We will use contract when meaning the standard expectations posed on graduates or Ph.D. holders, reserving curriculum for the syllabus being learned by undergraduate and graduate students.

1.1 Mathematics and Mathematical physics

Within the epistemological roots of mathematics the notion of “correct result” is directly linked to the idea of a perfect, continuous logical construct that takes from hypothesis to thesis proving the given statement (theorem, lemma, proposition, ...) using the rules of (mathematical) logic. Physics adds to this logical structure of mathematics the goal of providing an interpretation of natural phenomena. Observations or experiments, filtered through some interpretative network, act as corroboration or eventually modification of the specific physical hypotheses.

Since the times of Galileo, mathematical physics has been a full part of physics, sometimes known as theoretical physics. Mathematical physics takes the laws of physics corroborated in observations and encrypted in mathematical terms and draws conclusions from them using mathematical reasoning.

The connection with observations is at the root of the main differences between the physicists’ and the mathematicians’ use of mathematics. While mathematicians tend to emphasise theorem proving, i.e., the logical process of finding relations between hypothesis and thesis; physicists tend to use proven results to transform and explore the laws of nature. The emphasis put by physicists in transforming results opens opportunities for some confusion. Mathematics could then be viewed as “a set of transformation rules” leaving in a second plane the logic behind the rules.

Despite this difference in goals as to the use of mathematics, both sciences have the intention of producing a consistent logical discourse. In mathematical physics, many steps of this logical discourse consist of purely mathematical reasoning and as such it is subject to the consistency rules of mathematics. Physicists may take mathematical rigour a little lighter than mathematicians, especially when it comes to new mathematical objects with properties which are not yet completely understood, but when dealing with standard mathematical procedures such as sum or multiplication of integers, the concern for rigour is exactly the same in both sciences. Lakatos [10] observes this fact in the following terms:

> But *consistency*—in a strong sense of the term—*must remain an important regulative principle* [...] and inconsistencies (including anomalies) *must* be seen as problems. The reason is simple. If science aims at truth, it must aim at consistency; if it resigns consistency, it resigns truth. To claim that ’we must be modest in our demands’, that we must resign ourselves to —weak or strong—inconsistencies, remains a methodological vice.

1.2 Enculturation

Graduate students learn what theoretical physics is by the process of enculturation. The process of becoming a scientist proceeds by the participation of the student in research projects under supervision. In other words, it proceeds *by practice* rather than just by passive instruction. The meaning given by the students to the various objects they encounter in their work is shaped by “a process of interpretation mediated by social interactions” [6]. Campbell goes further and observes that, as the socialisation progresses, new members would have difficulties to see how things could be different from the perception of their scientific community.

Roth [14] emphasises that in the process of enculturation the students develop "habitus" (a notion that goes back to Bourdieu [3]), i.e., "systems of structured dispositions that generate structured actions". Roth observes that "Because of the structuring during enculturation goes unnoticed, acquiring habitus is associated with acquiring blind spots, ideologies and prejudices of the field".

The formation of scientists is strongly influenced by the agreement on what is a socially accepted argumentation for the local community. During the enculturation process in graduate studies, the craft (metier) of being a scientist (physicist, biologist or the like) is learned by "apprenticeship", i.e., embedded in the craft's (sub)culture [5]. This culture constructs the meaning and the rules of use for tools, working strategies, the concept of what is a "finished product" and many other things. It also shapes the social appreciation and approval (which constitute the rewarding system as much as examination and promotion are the rewarding system for undergraduates) as well as establishing which are the successful strategies.

By the process of enculturation, students adopt the "paradigm" of their community. Ritzer [13] defines

> A paradigm is a fundamental image of the subject matter within a science. It serves to define what should be studied, what questions should be asked, how they should be asked, and what rules should be followed in interpreting the answers obtained. The paradigm is the broadest unit of consensus within a science and serves to differentiate one scientific community (or sub-community) from another. It subsumes, defines and interrelates the exemplars, theories, methods and instruments that exist within it.

Publication of research results is an essential part of the formation of graduate students and "publish or perish" is arguably the main disciplinary policy enforced by the scientific community. It is likely that students that are slow in adopting the paradigm of their community will have a more difficult time publishing their findings, because of the nature of the peer review process. Indeed, this process scrutinises the presented results following the views and prejudices of the community of reference (at least in average). Furthermore, "confirmatory bias" in academic publishing is a fact [11].

In the following Sections we discuss these and related questions in terms of the "hidden curriculum", i.e., patterns of behaviour that students adopt as adaptive responses to demands coming -quite often unconsciously- from their teachers and advisors. We will describe and analyse the conflict between the hidden curriculum and the formal goals of both graduate education and research practice, contributing to understand the processes by which this conflict takes place.

2 Analysis of the problem

As stated above, we will focus on the modification of the concept of "correctness" and the subsequent weakening of the concept of "significant contribution" in

Physics. The choice of the subjects is biased by the authors' background.

We will address two examples where elementary mathematical controls are violated in refereed publications in well-known, high-standard scientific journals, subsequently cited without observations by colleagues in the same field.

The chosen examples are special only in the sense that the laws violated and the controls that were not performed are accessible to first-year undergraduate students of science and engineering. In all other respects they are typical and to identify such examples is a simple exercise for a well-trained alert reader *not belonging to the same local community.*

2.1 Mathematical background. Example I

A fundamental concept in mathematics is that of equality. No mathematical process can alter the fact that two numbers (quantities, expressions) are equal or not. In particular, equality between different numbers such as 1 and 0 or even worse ∞ (which is not a usual number but a more complicated concept) is impossible. This is not affected by the fact that in e.g., approximation problems one may choose to regard as "equal for all practical purposes" two numbers which lie closer among themselves than a given tolerance threshold. On the contrary, the concept of ∞ refuses any identification with a finite number whatsoever.

In [9] the fundamental concept of equality is violated. See the Appendix for a display of the relevant equations. Compare equations (2.5) and (3.49) for $t = t'$ and $\zeta = \zeta'$ and verify that the first equation yields 1 while the other –which differs from the first one in at most a complex factor of modulus one, according to (3.7)– would take an infinite value.

2.2 Mathematical background. Example II

Heaviside defined the step function to be zero for negative values of the argument and one for positive values. The actual value of this function at $x = 0$ is conventionally taken to be one, but it is usually unimportant in most applications. A fundamental property of this function is the fact that it is discontinuous at $x = 0$ and hence cannot be approximated around zero in the way in which analytic functions are approximated i.e., via a Mac Laurin series.

In [20] another violation of the mathematical laws occurs, where zero or some other constant "equals" inexistent quantities. This explicitly impossible operation is performed by replacing the Heaviside function by the continuous function $f(x) = x$ which has properties that contradict those of the Heaviside function for the purpose of the analysis. This result is cited in other journals and further developed in [8] where the (non-existing) derivatives of the Heaviside function –as a function– at $x = 0$ are assumed to exist and take a finite value. See the Appendix for details on the formulae.

Hence, the main question of this manuscript is: Why do some groups within the physics community accept and reproduce manuscripts which are "obviously wrong", within their own (mathematical) quality control rules as stated in the learning curriculum?

2.3 Interpretation: The social curriculum as a hidden curriculum

Are the examples presented above cases of "blind spots" of some (local) communities of practitioners of Theoretical Physics? Is the paradigm of some communities of Theoretical Physicists contradictory (not just different) with the paradigm of Mathematical Physics?

How come that elementary mathematical controls such as checking equality are overlooked by researchers, referees and subsequent readers ([8, 20] add up to 97 citations; while [9] presents 32 citations)? Is there a pragmatic pseudo-mathematics in which correct procedures is what results from symbol manipulations that are socially accepted within the sub-community?

Let us analyse first the nature of the violations to the learning contract displayed by the examples and their relation to the social curriculum.

Somewhere along the way, the natural controls developed by mathematics (i.e., to check that two things are equal in a way which is compatible with standard practice from the moment of their definition and throughout a manuscript, the existence of limits and derivatives, etc.) have to be suppressed. The meta-conceptual controls have to be (unconsciously) compartmentalised: Such and such procedure is required within the mathematics course, but "in real life" we do something different. This might very well be the case if one completely avoids mathematics and mathematical logic in whichever "real life" application that is considered, but it becomes an unavoidable conflict when scientific conclusions are supposedly based upon mathematical procedures and mathematical logic.

Compartimentalisation is a strategy that is incorporated possibly as part of the hidden curriculum in undergraduate studies, especially in the cases where physics teaching rests heavily in the use of analogies [19]. It is efficient for the resolution of the conflict between curricula and as such it might emerge as an adaptive response when enculturation operates a modification of (part of) the rules stipulated in the learning contract. Social factors produce thus a hidden curriculum that prevails (in case of conflicts) upon the learning contract. This hidden curriculum has at least two elements:

- The evaluation system implies that publication of articles (in reviewed journals) produces satisfaction and relief. The stimulus is placed on publication rather than on understanding (mastering). The examples above show that these things are not always equivalent.
- The concept of "truth" or "correct" is shifted from *there is a flawless logical chain between what I previously knew and the new result* towards *the argument was accepted by the audience* (or its variants: *it is in the book*, *it is published*).

In other words, the acceptance of an argument ceases to follow from compatibility with our own meta-concepts and with previously accepted and tested knowledge, in order to adapt to the new social pressures. Successful social behaviours are adopted or dropped as measured by social success.

In fact, when all other fellow students have published a couple of 4-pages papers, it produces a certain anxiety in the graduate student to still be working in the first, comprehensive, 30-pages long, manuscript. Adaptation to the community paradigm alleviates this anxiety, acting pretty much along the lines of classical *negative reinforcing* [7].

Some particularities of our examples are worth mentioning. The second group of examples [8, 20] is also an example of a confirmatory strategy since the results produced were in exact coincidence with widely held pre-concepts of the community [2]. Confirmatory bias [11] might have played a major role in the success of the work. The story of [9] is more complex [17]. The original theory was accepted despite its faulty mathematical logic. Its construction was analogic and based on "accepted manipulations". Alternative, more logical, theories appeared along the years but were socially unsuccessful. The theory was eventually disregarded because its predictions were inconsistent with experimental tests, i.e., it was disregarded because of its "physics" despite the fact that it was inconsistent and hence not a theory at all.

These processes exemplify the practising of a pragmatic pseudo-mathematics: formal manipulations are validated or rejected according to the end results rather than according to the conformance to a flawless logical process.

2.4 The dawn of a new "science"

One possible consequence of the above interpretation is that a combination of different social factors has produced a non-scientific "monster". Indeed, the examples mentioned above, despite coming from published articles in respected physics journals, violate the common core of Mathematics' and Physics' epistemology. We are left with an obvious mathematical error without support in any scientific curriculum. The only support for such (pseudo)results is of social character: The conventional agreement in taking them for valid since they are published in respected scientific journals.

One of the goals of this manuscript is to investigate how this "monster" operates in the formation of prospective scientists (who would never have done such elementary errors during their graduate courses), which we will develop below, and another is to try to understand the nature of this monster. Indeed, the epistemology behind these errors and others of the same sort is that "correctness" is the result of formal manipulations of symbols that the community has adopted as acceptable (formal series expansions, and formal path-integrals in the examples) but without other support, be it experimental or logical.

2.5 Social forces at work

The process of extending the domain of the social curriculum to the expenses of the learning curriculum is not free of conflicts and it is nourished by social forces.

Ph.D. advisors are also subject to social rules. They have to adapt to social pressure and may need to publish quickly a large number of papers in order to remain competitive in the labour market. This fact may trigger the temptation of inducing the graduate student to focus on problems and/or procedures that lead to fast publication rather than on a thorough education in scientific practice.

The immediate needs of the advisor enter thus in conflict with her/his pedagogical role in the formation of a young scientist. Even worse, this strategy may be considered as the correct one by the graduate student, since she/he also feels the urge for publications. One of us personally remembers being seriously worried about his future as a scientist a couple of decades ago when after one year of Ph. D. studies no publication had been produced yet. Complaints by graduate students in this direction have been registered by both authors only too often.

There are even worse consequences of lifting the responsibility for correctness away from the learning contract in favour of social agreements developed for other goals. One example may be the occurrence of dogmatism and utilitarism. The situation may extend to the point that correct arguments are those that lead to publication, i.e., those which are more easily accepted by the community, regardless of their factual truth content.

3 Probing the hidden curriculum

The tensions introduced by the hidden curriculum, the adaptation of the students to the situation and the elements that actually enforce the hidden curriculum can be explored interviewing young scientists.

We studied a small sample of seventeen voluntary testimonies obtained as replies to an anonymous questionnaire completed using the Internet. Graduate students and recent (less than two years) Ph.D. in Physics working at a handful of universities in Argentina, the United States and Sweden were invited to cooperate with the project responding to exactly the same questions (written in English). Although the present survey has clear limitations (small sample size and the impossibility to assess if the motivation to answer the questionnaire is a factor that biases the results), the clear and explicit nature of the answers makes us confident in the relevance of the following analysis.

The questionnaire included eight closed questions that in most cases could also be complemented with a brief explanatory phrase. The questions were aimed towards identifying to recognise the existence of a hidden curriculum making provisions for detecting possible denials of its existence; testing the relevance of a few elements in the rewarding structure that could be eventually (partially) responsible for the sustainment of the hidden curriculum; and finally testing the validity of the main thesis of this work, namely that correctness belongs to both the learning contract and the social curriculum.

At the following address: `http://www.maths.lth.se/~mario/quest.html` the reader can find the text of the questionnaire and the final results. We will discuss in what follows the outcomes of the questions that contribute substantially to the conclusions.

3.1 Acknowledging the existence of a hidden curriculum

Prospective scientists were first asked

> Let's assume that you have some new knowledge you want to share with your (worldwide) scientific community. Rank according to your preference the following communication strategies:
>
> 1. Communicate your new insights rapidly as they are being produced, thus publishing a number of short papers during your research.
> 2. Work 'silently' organising your study and produce one comprehensive paper at the end of the cycle.

3. Work 'silently' organising your study and produce a number of shorter, more accessible papers at the end of the cycle.

> Which is the advantage you perceive for your top-ranked strategy?

The first question was followed by

> Rank again the attitudes in Question 1 according to your perception of what the majority of the young scientists in your field do.

The first option given to the students clearly contradicts the learning contract making it a difficult choice unless an openly pragmatic approach to research is taken. However, when offered as option for a perceived (external) behaviour, this restrain is lifted.

Four answers made the fast communication strategy their own while nine answers accepted it as a third choice. Twelve answers ranked as their first choice either the old style approximation presented as the second strategy or the third strategy (which is also compatible with the learning contract).

Students that took the pragmatic point of view argued that the perceived advantage was: *Getting publications early is the only way if one wants to be able to apply for grants during the phd studies. Also fellow scientists will see what I'm doing and hopefully have some important input to contribute. Besides that when applying for money from different institutes etc. a publication with results is always good.* Another student expressed the perceived advantage in the characteristic cynical manner of utilitarism as: *money.*

The students making the "correct" choices (those which fit with the learning contract) argued in terms of: *Work 'silently' is the best way to get a deeper knowledge in a specific topic. Producing a number of shorter, more accessible papers it's, in my opinion, the best option mainly thinking in the potential readers of such papers. Each reader can to select what piece of my work it's of his/her interest* or: *Diminish the final amount of garbage, augment the amount of effective knowledge.* Some of these students went on to recognise that the pressure of the system renders the strategy of choice difficult: *There are too many 'unready' papers available. I would prefer fewer (and better) papers, but as it is now people still count the number of publications so in practice you are forced to do alt. 1.* The tensions introduced by being subject to two different and partially contradicting curricula are evident.

When the same strategies were presented as the perceived attitude of the scientific community to which the respondents belong, 76% of the answers indicated the first strategy as dominant. Our conclusion is that there exists a widespread habit of publishing results for reasons belonging in the social realm. This habit is clearly perceived by the respondents and, in combination with their own interpretation, apparently it reflects the existence of a substantial number of "research" papers which are either incorrect or that never reach their presumptive audience. This fact is recognised as a social habit of the scientific community based on reasons foreign to the scientific substance (money, work opportunities, group pressure).

The second pair of questions read:

> Rank the most influential factors when it comes to select the Journal where you intend to publish your work.

1. It has the audience I want to reach with my new results.
2. It has a high (the highest) impact index among the journals of this field.
3. It is where I have found the most interesting papers related to my work.
4. My supervisor says it is a good choice.
5. Other. Please tell us.

Subsequently the same question was posed for the perceived strategy of the community.

The first strategy was the first choice for six students, while the third and fourth strategies were each the first choice of four students. Three students chose the second strategy. As the perceived attitude of the community, strategy two had six answers and strategy four had five answers, while the remaining answers chose strategies one (three cases) and three (one case).

When answering about the personal options, the pragmatic second strategy is mostly avoided, while it is perceived as a frequent attitude in the community. The fact that the fourth strategy has a considerable frequency both for the community and the respondents suggests that a significant amount of students is not trained in choosing the target public for their manuscripts leaving this task to the advisor, a failure probably related to the conflict of interests discussed in (2.5).

The answers to these two pairs of questions capture the dichotomy between the perception that the respondents have of themselves and the perception they have of the community, being the self-perception mostly within the boundaries of the learning contract while in contrast, the community is perceived to follow the hidden curriculum operated by influences from the social curriculum.

3.2 Tensions and conflicts

The answers of the previous section go beyond the recognition of the existence of a hidden curriculum. It is clear that the respondents experiment tensions because of the opposition between the learning contract, which most of them support, and the social curriculum which they experience as an imposition of the community by way of the promotion and funding systems.

To deepen the understanding of these facts, the following question was presented:

> Most often than not, a graduate student works in a project within the research interest of his advisor. There is then the goal of developing the research subject itself as well as the goal of developing the graduate student into a junior (independent) scientist. Having two different goals there is always room for a conflict of interests.
>
> Can you recall situations in which you perceived a conflict?

There was 29% of *yes* answers, that is five students have perceived conflictive situations. There was however no preferred strategy to deal with this conflict. This indicates that the social structure of the scientific community is subject to structural tensions affecting the group. Apparently, not only the students but also the advisors are subject to conflicting demands.

3.3 Correctness and the social curriculum

The final question we will discuss reads,

> Most of the time in our research work we need to rely on results found by other scientists. Which of these statements are close to your attitude ('published' refers here to 'published in the most respectable journals of the area'). You may indicate as many as you need.
>
> Choices:
>
> 1. I will use published results regarding them as correct unless they have been refuted in another published work.
> 2. I will use published results if I trust the proficiency of the author.
> 3. I will use published results only if the results are obtained with methods I am familiar with.
> 4. Other (explain below).

Strategy one received seven answers, number two eight answers and number three received five answers. One answer took the fourth strategy, explained as: *I will use the results anyway (only for respectable journals).*

This question differs in a substantial way with the previous ones. Firstly, it is not completely obvious which answer(s) is(are) compatible with the learning contract. This allowed us to ask directly about the strategies of the interviewed persons, since there was no apparent need to distinguish between the own strategy and the perceived strategy of the community.

We interpret the result as follows: Almost one fourth of the answers are compatible with judging published results according to the academic criteria explicit in the learning contract (i.e., the third strategy, namely that only what is correct –in the sense that it at least passes the standard meta-conceptual controls for reasonability, validity and consistence–, can be used for subsequent research). On the contrary, the remaining answers either rely directly in publications as a consequence of the social curriculum (first strategy) or follow an authority principle (strategy two and four: I trust the book, journal, author, professor, etc.) which is simply the extension of the undergraduate curriculum[3]. This last alternative was chosen by about half of the respondents. Although option three is compatible with the learning contract, it is a rather weak formulation of the ideals of seeking the truth. Nevertheless, nobody felt the need of stating a more stringent formulation.

It is remarkable that (as we expected) there is no perception of a conflict between the learning contract and the hidden curriculum coming from the social curriculum in this point. In the previous questions, where we regarded this conflict as too evident, the interviewed people answered, regarding their own behaviour, according to the syllabus of the learning contract, while the answers about the perceived behaviour of the community reflected the social curriculum as a hidden curriculum. Apparently, there is no awareness of the existence of a conflict between social and learning curricula in this respect.

[3]Whether it is the hidden or the explicit curriculum is an interesting question in itself. See [19] for a discussion supporting the idea that it is the explicit curriculum.

4 Summary and Discussion

This research effort spawns from the observation of a surprising number of published works in high-standard refereed journals that not only present results which are clearly incorrect, which we believe is nothing more than a contingency of scientific work, but that also display an impact (measured by citations) far from being negligible.

We have provided evidence regarding the role taken by the social curriculum as a hidden curriculum concerning the rewarding structure of science and its conflicts as opposed to the learning contract. This process is related to the development of blind spots and epistemological prejudices in the process of enculturation, the effect of confirmatory bias in and beyond scientific publications and the emergence of a pragmatic pseudo-mathematics resting upon socially accepted manipulations of symbols violating the common core of Mathematics' and Physics' epistemology.

The contractual shift (from learning contract to hidden curriculum) can be understood in terms of the use of evaluation methods that sense secondary effects of the principal goals. A goal of research could be "simplified" in the phrase "I understand a new problem and publish a manuscript thereafter". The principal goal is understanding, the (important and necessary) secondary effect is the publication. Measuring the degree of understanding new problems in terms of publications may be misleading since the latter can be produced without the former (see the examples). The measuring method induces an enhancement of the social relevance of publication and a corresponding relevance reduction for "understanding new problems".

The case against the use of citation indexes is even stronger. As shown in the examples, important citations numbers can be achieved with incorrect results as long as the thinking is "socially correct". Citation numbers are to a very large extent a measure of a successful communication strategy and of the fulfilment of the social curriculum.

The inadequacy of the secondary indicators of scientific activity (number of publications and/or citations) had been known for a long time [15]. However, using these indicators (among other indirect indicators of social character) is still the proposed mechanism to assess "high scholarly quality" [18]. Our perception, supported on this manuscript's discussion, is that these indicators are not only insufficient to guarantee the quality of research, but in addition they effectively lower the quality standards of scientific practices adopted by local communities, as the examples above illustrate.

A small set of non-personal interviews makes clear and evident that prospective and young scientists are painfully aware of the existence of a hidden curriculum, a curriculum that most of them resent as imposed upon the students by the promotion, evaluation and funding systems.

Furthermore, we have given elements that support our claim that, somehow unexpectedly, "correctness" belongs in both curricula. In this respect, there is no awareness, much less distress, on the contradictions of the enhanced learning contract, the social curriculum and the (undergraduate) hidden curriculum. Criteria of correctness emerging from these three different norms coexist, being the most frequent attitude in the survey, the persistence of the hidden curriculum in the undergraduate learning contract. In this respect, the renegotiation of the learning contract upon graduate studies and research activity is not successful.

Our experience as reviewers concurrently with the survey results, support the idea that correctness has a strong social component. A handful of times we have found that authors try to refute observations about the logical consistence of their manuscripts with a list of references where they claim that the same procedure is applied. In other words, to a criticism in the consistence of a manuscript entirely within the learning contract, we receive an answer where the argumentation is supported on social criteria ("it is accepted practice").

This detected change in the "correctness" criteria contributes to understanding the reasons why local communities have problems in scrutinising the quality of their own scientific production. To members of different but related communities certain evident problems (as our examples) produce an effect reminiscent of that in H. C. Andersen's tale "The emperor's new clothes" [1]. Leadership and trust in the social controls (peer review) allow prospective scientists to neglect their direct responsibility regarding the correctness of their finished scientific contributions as a whole. This *selective negligence* is a behaviour reminiscent of the adaptations described in such terms in [16].

A majority of the prospective scientists interviewed take full responsibility for their contribution to their final scientific products but transfer the responsibility of borrowed results to the social organisation. This substitution of the statements of the learning contract by those of hidden curricula parallels the changes in the perceived responsibility operated in the process of industrialisation: when craftsmen evolved into industrial workers they lost control of the outcome of the production process as a whole. Actually, this observation is very much in line with the main thesis in [12] where it is noted that the funding system developed in the last 50 years operated a dramatic modification of the production structure and culture within the university, comparable with the effect of the protestant Reformation in the religious structure of Europe.

Following Snyder [16], we speculate that the learning contract has not adapted to the modification of the production mechanisms in science. From the "handicraft" era of Einstein and Bohr at the beginning of the past century all the way to the small incremental contributions of today's scientific production, a change has taken place at a pace that the updating of the learning contract did not follow. Consequently these changes have been controlled by the hidden curriculum.

4.1 Proposals for the future

The effects of some of the detected problems can be mitigated with relatively simple measures. For example, the "emperor's clothes" effect is only possible in closed and self-referent local communities. Enlarging the review process to systematically include other than just the specific experts in the subject may help to avoid the most evident contradictions. In the same sense, the teaching of mathematics should generate the internalisation of its control methods so that their application is not restricted to the context of learning mathematics. The methods of mathematics and its meta-conceptual controls should be transferred in a more efficient way to the scientific contexts where mathematics is used.

As long as the reward system keeps supporting the hidden curriculum (many low-quality publications are in practice better than few high-quality ones for the survival within the community), conflicts of some sort are bound to appear. One way out of the problem is to modify the social agreements. Measures such as counting papers or citations are the most evident forces influencing the social success and the hidden curriculum. We believe it is necessary to replace them with more meaningful ways of evaluating scientific production.

4.2 Disclaimer

The authors are far from believing that they are free from the influences and problems described in this manuscript. They can at most claim to be aware of the situation.

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Appendix: Details on the formulae

The relevant formulae in [9] are equations (2.5), (3.7) and (3.49). The first one reads:

$$K(\zeta'', t''|\zeta', t') =< \zeta''|\exp(i\hat{H}(t''-t'))|\zeta' > \tag{1}$$

or $t'' = t'$ and $\zeta'' = \zeta'$ this expression takes the value 1. This same quantity K is approximated in eq. (3.7) in a "semi-classical" way as:

$$K^{sc} = \tilde{K}\exp(iS_{cl}/\hbar) \tag{2}$$

The complex exponential factor has no relevant influence in the final comparison, since it has modulus one. Hence, for $t'' = t'$ and $\zeta'' = \zeta'$, $\tilde{K}$ should be another complex number of modulus one, so that the product has a chance of taking the value one as stated in the first equation. However, when working out the example $\hat{H} = -\omega\hbar J_z$, equation (3.49) computes:

$$\tilde{K} = [2\pi i\hbar \sin\omega(t''-t')]^{-1/2} \tag{3}$$

which goes to infinity as $t'' \to t'$. We note on passing that $K(\zeta'', t''|\zeta', t')$ can be explicitly computed for the proposed example as:

$$K(\zeta", t"|\zeta', t') = \frac{(1+\zeta"^*\zeta' \exp(i\omega\hbar(t" - t')))^{2J}}{(1+|\zeta"|^2)^J(1+|\zeta'|^2)^J} \times \exp(-i\omega\hbar J(t" - t'))$$

The approximation of (3) carefully using the stationary phase and related methods gives indeed the exact result in the present case. See e.g., [17] and references cited therein.

In reference [20], eq. (38) states:

$$\Theta(x) \approx 1 + \sum_{k=1}^{\infty} A_k x^k \tag{4}$$

as a proposed Taylor expansion around the origin of the Heaviside function, $\Theta(x)$. There exist no constants A_k which make the equation correct, not even in the approximate sense. The first terms of this "expansion" are later used to derive what is called the *Arrhenius model*. Noticeably, the authors are somehow conscious of the daring step, since they state: *If the foregoing can be justified...* No further analysis or justification is present in the manuscript.

Reference [8] cites [20] in producing the same "expansion" of the Heaviside function and even of the Kronecker delta symbols (which are discrete). In fact, equations (A7) and (A8) state:

$$\Theta(\pm x_i) = 1 + D_0^{\pm} \tag{5}$$

where

$$D_0^{\pm} = \sum_{n=1}^{\infty} \frac{(\pm x_i)^n}{n!} \left. \frac{\partial^n \Theta(\pm x)}{\partial x^n} \right|_{x=0} \tag{6}$$

Needless to say, the partial derivatives (which perhaps should be total derivatives?) do not exist.