The Persuasive and the Convincing: In Search of a Functional Characterization of Educational Interventions in Science

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Addressed to professionals and researchers, this article proposes a reflection on the issues and risks associated with certain uses of labels that allow qualification of tested, promoted or contested pedagogical practices and interventions in science education. Often paired in dichotomies, these labels are here presented as sometimes generating credibility problems for research efforts that invoke them, as well as misunderstandings and prejudices when imprudently invoked in teacher training. The article thus proposes an original, dichotomous, and functional formula for characterizing educational efforts, drawing on the ordinary difference in everyday language between persuasion and conviction.

Keywords: science, teaching, research, teacher training, persuasive, convincing

THE PROBLEM OF LABEL FUNCTIONALITY

While virtually unavoidable, it is admittedly brutal to assign a single label to characterize something as complex and extensive as an educational practice or intervention. Yet this is widely done not only in the media and newspapers, but also in academic and research settings. One may choose to do so out of methodological reductionism. Although this may have no restrictive ambition, it nevertheless flattens the multidimensionality of a certain reality to a single essence, useful to the researcher; but at least partially unjust. One can also attribute a practice or a didactic intervention with a single label in order to present them in an abbreviated manner: somehow "making an image," and thus accelerating or promoting some demonstration of value. It is important, however, to be clear about the possible misunderstandings, risks, and prejudice that such reductions often cause.

In this article, we will first situate the said problem of functionality inside the research world, by presenting some of the possible negative consequences typical of publications and communications from educational research. We will then present the problem as it exists even more clearly, but for other reasons, in the context of teacher training, with an emphasis on in-service education. Only later (in the second part of the article) will we propose a possible partial solution to the problems that have been raised, by

suggesting the use of an original dichotomy, which we believe may be useful. Finally, we will present a general discussion on the ambitions and limitations of the proposal.

THE CASE OF COMPARATIVE RESEARCH

There is currently a trend in school systems according to which interventions and practices should draw more from research-based knowledge. And as is the case in science, well-done *comparative investigations* are among the most likely to contribute to the field (Geis, 1984). Indeed, one cannot easily be convinced of the value of research pieces that merely present the results of a single post-surveys, or simple differences in the effects on a pre- and post-test of a given dependent variable. Any recorded progress would inevitably be trivial and therefore of little interest, since any well-intentioned intervention, even the most mediocre one, necessarily lead to at least some learning progress. In university courses on research methodology, it is often repeated that adding a control group to quasi-experimental research designs is necessary, not only to secure a comparison of possible gains, but also to control for test effects and, in some cases, for other confounding variables.

However, in educational research, the use of a control group or control condition implicitly suggests that the learner that populate it are not subject to the variable/intervention/practice being tested, while the participants in the experimental condition or group are. The hope is to obtain a comparison of the effect of a presence with its absence. Tacitly, the "control" condition is likened to the distilled water often used in chemistry.

However, what happens in the control group of an educational research is never insignificant, or negligible. Moreover, even if we were to try and make the most banal pedagogical treatment imaginable, it would necessarily imply, despite our possible voluntary blindness, multiple and synergetic interactions between learners, as well as the triggering of highly complex and incontrollable reflections. The teacher's discourse alone, however transmissive and unidirectional it may be, remains capable of unleashing intellectual hurricanes that respond much more to the dynamics of chaos than to methodical construction. The cognitive itineraries of the learners, no matter how invisible they may be, can then react unpredictably to the slightest word and drift towards the unexpected, or otherwise create magnificent and extraordinary intelligences, lasting passions as well as deep wounds. We need only think of the teachers who have inspired us the most. They have not always used sophisticated teaching techniques; their results have always depended largely on their understanding of their student's specific receptivity, as well as hundreds of other volatile variables.

Here, we are not attempting, nor do we intend to question the value of educational research on the grounds that it deals with phenomena that are too complex to be adequately controlled or modelled. On the contrary, we believe that strong and precious convergences can still be recorded, beyond noise, as long as the research protocols are well done. This is merely normal issues for the research being published every day. However, we assert that control conditions are inevitably very rich, despite possible initial assumptions. But also, that any assumption that "nothing" is happening in control groups could be tantamount to blindness.

Thus, for comparative experimental or quasi-experimental research to have any value, it is absolutely imperative to characterize, as precisely as possible, not only what happens in the experimental treatment (i.e., the independent variable), but also to describe what precisely happens in the treatment that serves as the basis of comparison (one may also choose to speak here of a "comparison group"); to tell their similarities and differences. Thus, if there are differences between conditions, we will know precisely what to attribute this difference to. In short, without a functional and convincing characterization of each of the groups being compared (similarities and differences), beyond the presumed presence/absence of the variable under study, the power of the comparisons involving them collapses.

Some researchers will try to sidestep the difficulty. We see them testing the interventions they prefer, for good or bad reasons, by comparing them to what they will then call *traditional*, *customary*, or *usual* treatments. Here, it is understood that they recognize that control groups are not ultimately full of dummies and that the teacher's discourse is not just noise or reading. Also, we may suspect, and rightly so, that the

ambitions of these researchers are probably limited to teacher training; that is, they are primarily interested in eventually informing educational practitioners and decision-makers about what might happen in the specific case where, for example, they decide to implement a particular intervention mode, as compared to the eventual choice of doing business as usual instead. This is an intention based on the legitimate goal of moving the profession toward better devices and solutions.

It should however be recognized that in much of this research, groups labelled as traditional are not often systematically observed or characterized in a sufficiently satisfactory manner. Consequently, without sufficient knowledge of what is contained in the comparison base used, the net value of the exercise is unfortunately cut in half.

It remains possible, of course, that the concept of *traditional education* or *teaching* and its synonyms be highly evocative for most people involved in education, and therefore, that the absence of their description may not generally felt as problematic. However, it must be recognized that there is no guarantee that such a simple evocation will generate understanding that is consistent from one person to another. Traditional teaching is therefore not an independent variable that can be dissociated from the personal or institutional cultures in which it is measured or understood. We tend to believe that it is rather a kind of scarecrow, which is somewhat elusive and difficult to accept from a scientific point of view.

Other researcher, still under sufficient confidence of knowing enough about what can be found in a traditional classroom, will allow themselves to specify the label. The basis of comparison for the comparative research they conduct is then called *frontal*, *direct*, or even *encyclopedic* teaching. The scarecrow, presumed to be the apostle of the exclusively communicative paradigm of teaching, then becomes the "bogeyman." In practice, it is then much easier to morally oppose the methods (i.e. treatments) that are presumed desirable: scientific investigation approaches, active approaches, discovery learning, sophisticated interactions, STS approaches, socially active questions, conceptual changes, etc. At this, we are edging close to the classic battle of good versus evil. We would like to warn you: in general, it is expected that good will triumph.

It remains also very difficult to affirm that control treatments are entirely devoid of what can be found in experimental conditions. One can very well imagine the existence of an oral discourse that a teacher would address to his or her students, and that would deal with the characteristics of a good scientific investigation, thus helping them to better succeed when they will actually experience it. Another possibility is a relevant lecture on the proper conduct of scientific debates, on socially relevant issues, or on the impact of science on economy, environment, and society. A teacher, in order to instigate a conceptual change, can certainly give a sophisticated demonstration, but he or she can also tell a well-contextualized historical anecdote and show how and why one scientific idea deserves to triumph over another. In this sense, labeling a pedagogical intervention as *"teacher-centered"* is hardly a guarantee that it can be in total opposition to methods that are deemed preferable or sophisticated, like for example socio-constructivist ones. One can therefore also succeed in activating students' minds even if they sit and listen. If this is at all accepted, then the conclusions drawn from caricatured comparisons may be weakened unless they have been "fudged" from the start by artificially exacerbating the difference between groups, possibly to the detriment of the control group populations.

Meta syntheses and metanalyses also regret this: the research they identify and synthesize too often rush and botch the characterization of control groups, in some cases weakening the value of the yet powerful statistical calculations they perform. In a meta synthesis on students' interest, Potvin and Hasni (2014), for example, explicitly regretted that the research they surveyed so easily came to positive conclusions "because of the banality of what happened in the control group" (p.108). Similarly, Schroeder and colleagues (2007), in concluding a meta-analysis of the effects of different categories of science education interventions, complained that treatment comparison bases whose weighted effects they compiled too often refer to an overly fuzzy conception of the "direct teaching" label that was very frequently associated with them. They also referred to Li and Klahr (2006) who extend their complaints to independent variables, i.e. the labels assigned to the experimental treatments:

> *The "direct instruction" label is sometimes intended to mean a highly specified instructional procedure, mainly for reading and math, developed by Engelmann et al. (1991): at other times it is used much more diffusely to mean a wide range of teacher-controlled talking, showing, questioning, and demonstrating. "Hands-on science" and "discovery learning" are even less well-defined terms that usually allude to various mixtures of physical manipulation, guided inquiry, and student exploration. Such lack of precise operational definitions has allowed earnest, passionate, but empirically ungrounded debates to flourish in the area of science instruction policy (p.19).*

Comparative research in education, which uses experimental and quasi-experimental designs, would therefore likely benefit from better monitoring of the quality of the labels it assigns to the conditions it contrasts. The credibility of their conclusions depends on it.

DISCOURSES DEPLOYED DURING TEACHER TRAINING

Other activities in education, such as the teacher training, would also benefit, though for different reasons, from a closer look at their characterizations and use of "labels." In the course of our teachers' training observation activities, we have often had the opportunity to notice that labels are often used in an inconsiderately reductive manner. Used too lightly or sometimes without minimally satisfactory explanations, their presence should immediately arouse suspicion. However, perhaps because of the frequency of their use, we are accustomed to them, and our defensive reflexes seem somewhat weakened.

In continuing (in-service) training, for example, the labels that are commonly used and referred to in talking about pedagogical interventions can do considerable damage, but unlike the problems of scientific credibility that they generate in research, these labels are sometimes strategically exploited by the authorities to support and feed their persuasive efforts. They are thus very useful to them. Indeed, shouldn't concepts serve for improving educational services?

Perhaps the most common of these labels is that of "teacher-centered" interventions, which is then contrasted with that of "student-centered" teaching or learning. The image is powerful because it mobilizes not just one, but two labels simultaneously and dichotomizes them, suggesting an inscription of any interventions somewhere along a continuum that extends from, in fact, the undesirable to the desirable.

Let's face it, it's hard to argue that there isn't something true and relevant about this dichotomy: we all know teachers who seem to be woefully lacking in cognitive empathy and sensitivity to the individual characteristics and needs of those they teach. At the other end of the spectrum, the image of other teachers, who are very different, may come to mind. They are people who have challenged us, more than they have given us, who have truly challenged us, and not merely spoken to us, and who have made us experience things, made us grow, more than they have simply told or informed us about them. They are good teachers who have succeeded in reaching out to us and thus changing us; who want to make "well-made heads" rather than simply "well-filled heads" (Fourez, 2002).

By evoking such extremes, we perhaps wish to remind ourselves, in a constructivist spirit, that intelligence is a living and adaptative force, a mill for constructing meaning, a tireless interpretative machine, and that learners are not all equal. We want to remind that it is in and through students that learning ultimately takes place; and that transmitting knowledge to them through oral presentations, however impeccable they may be, is probably not enough to produce valid or profound learning and development, or to secure the integral development of learners (Legendre, 1983) and of truly educated beings (Legendre, 1995).

While they may indeed motivate and even mobilize a few teachers, the ideas of *teaching-centered* or *student-centered teaching-learning* interventions and their various variations (teaching paradigm vs. learning paradigm) are unfortunately not suitable to concretely equip anyone. Although their extremes make an image and suppose a suitable destination, between them they provide nothing usable, neither criteria, nor a path to improvement. If they can be useful to judge the past, they may not be as much to plan the future. Moreover, although they refer to things that one can easily imagine, in reality, practices that would

be purely or sufficiently this or that simply do not exist in an integral manner or are impossible to qualify absolutely.

Since both the teacher and the student are involved in each learning situation, and the presence and participation of both is essential to the success of the educational project, it is difficult to see how one could choose to exclude another. Yet this is what the dichotomy presented above suggests. It takes both a stronger spark and a better fuel to improve the performance of an engine. Not one at the expense of the other.

It is not uncommon for many teachers, who were initially highly motivated, to become frustrated with the in-service training curricula imposed on them, and then tend to become very resistant and reluctant to receive further training. We believe that this reaction is not only the result of the poor quality of the pedagogical content offered, but of the manner in which this content is being qualified, and the manner in which its supposed opposites have been labelled.

For example, there is no hesitation in presenting certain educational interventions that are widely used in schools as being insufficiently centered on the student. However, such a judgment can be very difficult to accept for some teachers, who are sometimes forced to use such interventions, not because they choose to, but because of the overload imposed on them (large groups, long hours, etc.).

They may also feel that some of their teaching preferences are legitimately labelled as lacking in altruism. Given the considerable amount of energy that teachers expend in an attempt to accomplish and maximize the impact of their work with students, it is absolutely normal, unfortunate, but predictable, that some receive this as a slap in the face. Some teachers literally live for their students. They think about them during breaks, lunch, family time and even during sleep. They plan for the next school year during their vacations, are constantly on the lookout for anything that will help them fulfill their social role of making students successful. Convinced of the importance of their action on developing people who are often vulnerable, some push their commitment to the point of exhaustion. We therefore do not believe that it is morally acceptable to suggest that their practice may not be sufficiently centered on students and thus, voluntarily or not, to question the quality of the fundamental reasons behind their involvement.

Encouraging for some, damning for others, the ill-advised and clumsy use of labels that can be perceived as guilt-inducing will also have the effect of increasing the division of the teaching staff into two sterile groupings (innovators vs. resisters), whereas solidarity in adversity should be at least part of the solution.

There are also other similarly clumsy attempts to characterize the interventions used in the classroom. Active versus passive learning is one of them. Let us start by acknowledging that research shows with some clarity that learning is indeed more easily derived from activity than from passivity. Some teaching practices that either compel or encourage it are actually better: voluntary and conscious position-taking (Albe, 2005); explicitly formulating hypotheses or predictions (Brod, Hasselhorn, & Bunge, 2018); requiring contributions to discussions (Lilly, 2012); allowing choices (Hasni & Potvin, 2015) ; metacognitive reflection (Schraw, Crippen, & Hartley, 2006); constrained reading intention (Boudreau & Beaudoin, 2015); taking charge in problem solving (Reigosa & Jiménez-Aleixandre, 2007); and so on.

However, most of the time, it is assumed that some interventions are in themselves practices that, wholly or essentially, maintain passivity or activity, when in fact, a thorough analysis of these practices reveals multiple possible qualifications. One can, for example, give presumably platonic “lectures,” which rather tend to trigger real ideological storms, even while students seem to be sitting “very quietly on their chairs.” One can also show a well-chosen film that has the potential to trigger violent cognitive conflicts and possibly even the conceptual changes that were originally intended. Conversely, one can also organize a nice field trip that is presumably active and dynamic, but ultimately cognitively sterile. One can have a demanding laboratory experiment that ultimately only serves verification of previously taught content, just as one can force a lively “scientific” debate, but which ultimately turns into a mere conflict of opinions. One can make a highly engaging educational video game play, but without any of the desired gains, etc.

Therefore, it is not just the great teaching methods deployed that matter. It is also the epistemological adherences and pedagogical beliefs of the teachers, as well as all the little gestures, the little words, the subtle constraints imposed, the reminders and the little effects that stem from these adherences and which

make a difference. These latter prove, in some cases, too often be even more decisive than the big pedagogical hardware of ideological origin that are deployed and eventually celebrated.

As for other dichotomies, they are also widely used in in-service teacher training with the aim of marking the desired direction (current situation → projected situation), but without there being any absolute or complete opposition between the "opposing" labels. Thus, sometimes, *transmissive* and *constructivist* are awkwardly contrasted without sufficient development, leading to the belief that the construction of knowledge is desirable and even possible, without a minimum of information transmission or a suggested conceptual basis. In the same way, teaching by *accumulation* of knowledge is contrasted with *pedagogy by competences*, suggesting that competences are developed independently of the existence of knowledge. Reprehensible *repetition* (or rote learning) is contrasted with desirable *understanding*; whereas all competent musicians and athletes will not hesitate to swear that they excel through repeated practice. We also contrast the *authoritarian* with the *democratic*, without remembering that not everything in the classroom can be achieved by deliberation and that there must still be a leader who "knows best" and without whom there can be no likely destination, discipline, or sufficiently rapid progress. Students must also recognize enough intellectual authority to- or confidence in- the teacher, so that they do not to constantly doubt the value of what the teacher is saying. And all this would not prevent an authoritarian teacher from making his students experience and feel the democratic dimensions of the development of scientific knowledge.

Finally, in science education in particular, we sometimes oppose processes and products, or learning by communicative approach with learning by discovery. The use of such two dichotomies encourages barely concealed agendas. As such, focusing on the resolution processes is presented as being more interesting than evaluating the products, because the processes necessarily lead to the products. To be interested only in the value of the answers, for example, would take away the means to improve them. But isn't the quality of the outputs and responses a valid, albeit insufficient, indication that the processes were well carried out? In this context, one may ask why not consider both rather than oppose them and risk misunderstanding? Similarly, it is by no means excluded that it is possible and profitable to have students discover certain observations, relationships, and even some scientific laws through crucial experiments or demonstrations, exploratory approaches, or well-organized debates, but here is the thing: such pedagogical devices of discovery learning usually are, when they work, very closely, while silently, piloted by astute teachers who know exactly where they are taking their students to (Kirschner, Sweller and Clark, 2006), through the specific forms of the problems they submit them to. They then guide them rigorously with ingenious and well-constructed specifications in which they will have been able to communicate all the necessary information to make them pass through the diabolical pre-programmed funnel and ensure that they are sufficiently equipped to take charge of the resolution by themselves. As such, we are forced to recognize that in the act of teaching through discovery, there is sometimes a lot of information, but mostly the right information. Not necessarily all of it, but precisely that which generates the desired awareness and discoveries.

Let us, therefore, stop opposing communication and discovery; one will always be found in the other for any educational project that knows where it is going. Moreover, let us admit that one would have to be extraordinarily naive to hope for learning by discovery to the point of believing that one can make each student reconstruct, piece by piece, the entire scientific knowledge that is well present in the program, but that took centuries to be developed by entire communities of professional scientists. Let us also recognize that one cannot always doubt everything and that from a certain moment, a certain confidence in the scientific institution ends up being desirable to support an accelerated development of the culture. Thus, communication and discovery are both indispensable and participate in cultural development. To present them as opposites suggests that one must be obtained at the expense of the other, which is rather absurd. We nevertheless have often seen teachers believing that learning through discovery signifies letting go of all guidance, testing it as such, and just to end up failing to observe or record learning, and at the end giving up completely on doing anything other than providing information.

Nevertheless, teachers are generally not too fooled by the sterile dichotomies, but they do not necessarily understand well why- or do not perceive the added value of- these dichotomies that are being

presented to them. Thus, in in-service training, there is an often lot of resistance that might be, in fact, justified. Perhaps it is not felt as much in pre-service contexts where future teachers may not yet have had the opportunity to put the utilitarian value of such binomial labels to the test? The shock will however still happen, only later.

As researchers and teacher trainers, it is our moral duty to assign the label that best objectively represents the object it attempts to portray, with all due respect for professional reality, and for persons, and even if we still must motivate the troops and mobilize them.

THE PERSUASIVE AND THE CONVINCING: A DIDACTIC POSITIONING

Here, we do not wish to resist the use of dichotomies when talking about education. Dichotomies are useful and they often provide powerful tools for conducting effective explanations about how it is best to teach. However, in our opinion, invoking extreme opposites that are too far apart allows too many intermediate cases to be considered, thus often allowing somewhat of a paralysis, misunderstanding and confusion to arise as to the precise nature of efforts to be made.

Instead, we propose to present a dichotomy which we are yet to see appear in this particular form in the science education research literature, that we believe to be as simple as fertile, and that it is possible to consider in order to mark out certain educational efforts in research or training. This dichotomy will certainly not able to cover all the possibilities in a useful manner, nor will it replace all the ones presented above, as this is not its presumed function. We believe, however, that it could help, in some cases, to alleviate some of the above-mentioned problems. It is therefore a benevolent and humble proposal that we are submitting to the educational community, implicated in science education in particular.

Based on the nature of contents that characterize scientific activity (and perhaps technologies), the proposal is therefore more of a didactic than pedagogical nature. It could thus be more functional and useful than some other dichotomies in cases where one would try to label or characterize educational treatments that would aim at increasing their sensitivity to the specific properties of scientific knowledge and methods.

This dichotomy is based on the ordinary difference found in common language (ordinary dictionaries and others) between *persuasion* and *conviction*. Already, some readers could be in doubt as to whether there is any instructive or meaningful difference between the two. This reaction is positive, because not only does it lead to curiosity, but the great similarity between the two constructs also allows the debate to be cleared of several tensions that are nor constructive, nor useful.

Indeed, in all cases, both teachers (agents) and students (subjects) are obviously present and involved. None of them are taken out of the equation. In both cases, relevant, useful, and even essential information can be provided orally or through lectures. For both persuasion and conviction, it can be assumed that learners are active, work hard, and are able to adapt to circumstances (environments). Similarly, each label acknowledges that cramming, “teaching to the test” or teaching by shortcuts are to be avoided. In both cases, it is recognized that adherence to an educational program, a curriculum, is part of the teacher’s job; that it is possible to label large methods as well as small gestures; that it is possible for the teacher to resort to interventions of one or the other “type” for reasons beyond his or her control. Because activities of both labels can be presumed as legitimate.

The dichotomy also provides some grist for the mill: sometimes, for the same amount of energy expended, and all other things being equal, it is still possible to teach differently, persuasively, or convincingly, as long as these options are known and understood.

PERSUASIVE TEACHING

In the context of science education, persuasive teaching could be defined as any *teaching that seeks to effectively obtain the learner’s adherence to the programmed scientific propositions*.

We are not trying here to minimalize (reduce) the idea *of scientific proposition* to written or oral statements, or to their formulation, but to extend it to any knowledge element that has some utility in scientific activity. We could then extend it not only to those which, being essentially discursive, would be

the product of scientific activity (concepts, laws, principles, etc.), but also to any proposal of a methodological nature or of scientific skills. We could even think of attitudes and values, provided that these are derived, like the other objects considered, from science training programs.

This being said, the main motive in persuasive teaching remains the obtention of adhesions, that is, the ultimate requirement that the learner must make such propositions his own; that he or she subscribes to them or recognizes a minimum of absolute value; that he/she approves of them. Such endorsements can at least partially cover the ideas of understanding, using, and reflecting on the propositions concerned. One can indeed legitimately try to obtain by persuasion that the students accept, but also understand, mobilize, and reflect on targeted scientific propositions.

Adherence is obtained by means that are commonly used in our schools today. For example, persuasive teachers work to demonstrate to students the descriptive, explanatory, predictive, and exploitative value (Potvin, 2018) of programmed propositions through the presentation of cases that are essentially positive. In other words they will provide evidence of all kinds (experimental, authoritative, experiential, observational, demonstrative, anecdotal, etc.) that can support or reinforce a demonstration of power and enhance perceived value, utility, or merit. In short, the best possible evidence that best supports the value of the programmed propositions is provided. It is through this evidence and argument, its quantity and quality, that adhesion and habituation is fostered.

Since in this context, it is mainly the result (the "output") that counts rather than the means of achieving it, the problem of the effectiveness of persuasive initiatives is obviously raised and thus becomes central. The aim being to obtain, as quickly and efficiently as possible, the desired adhesions for the greatest number of students. We also want endorsements to be strong, too. Since class time and energy are limited, and the targeted progress and depth are immense and virtually infinite, the work of teaching can no longer be conceived as having to be completely achievable, but rather as having to be optimized.

Persuasive initiatives are often easy to recognize. Table 1 presents some of them and shows how they help to foster adhesion.

TABLE 1
CHARACTERIZATION OF PERSUASIVE INTERVENTIONS

Intervention	Target goals
Comprehensive, well-constructed oral presentations (led by the teacher)	To promote intelligibility, clarity, plausibility, and fertility.
The teacher is often at the front of the room, in full view of the students. Students listen attentively and quietly. Variation of stimuli.	To encourage attention, maximize hearing and ensure that no crucial information is lost.
All program contents are given similar attention and as considered as being important. The teacher must follow through on his or her planning.	To promote the acquisition of all targets.
Realization of comprehensive sets of exercises that allows for the mobilization of knowledge.	Appreciate the extent to which knowledge can be used to solve many and varied, yet related, problems.
Routines are encouraged. One way of solving problems is emphasized. Under pressure, "leaps of faith" are required and requested.	Accelerate adhesions.
Verification laboratory experiments	Provide a demonstration of the usefulness, power, or truth of what has been previously taught.
Historical anecdotes and "savory" narratives that recount and value the extraordinary contributions of past researchers	Insist on the beneficial effects of the related discoveries on society, the environment, the economy, etc.

In persuasive classrooms, there is also a strong focus on- and surveillance of- anything that might be wasteful. Thus, learning is primarily seen as an individual affair, as it is the adhesion of everyone that is ultimately sought after. Consensus and discussion may be concepts with high social desirability, but they are also sometimes seen as suspect; while collaborative exchanges may foster some desirable adhesions, they can also derail them through contamination. Thus, in this context, teamwork is used primarily for economy reasons, freeing up time to provide more and other positive pieces of evidence. In persuasive teaching, there is also a rather strong reluctance to systematically address students' errors and misconceptions. If exposed or repeated, errors can threaten or delay important endorsements through a risk of disseminating false information and generating confusion. Misconceptions are here often considered as unwanted noise and, as a basic rule for many experienced teachers, "one should never leave something wrong written on the board for long." Students' papers are also corrected in the same spirit: the mistakes are marked in red ink on notebooks, and it is hoped that student will more clearly see their failures to adhere to required standards. It is then hoped that they will quickly set about correcting their mistakes. In the interests of efficiency, persuasive teaching generally also ignores epistemological, psychological and metacognitive considerations, because even if their absolute scientific value can easily be recognized, their relative contribution to adhesions is more than dubious, given that the syllabus is full, time is short, and exams are usually not about that. Finally, in persuasive teaching, one does not necessarily pay much attention to added values of the teaching objects. We rather presume it is already there, and then we merely expose their advantages, their power, and the interest they should arouse.

We do not wish here to condemn this method of doing things, which is sometimes, in other words, too often, the only viable one. With overcrowded classes and overloaded programs, under the constraint of having to respect a sometimes difficult examination prescribed by the Ministry (or other authorities) and the pressure of parents, it appears normal that teachers start looking for mere adhesions as efficiently as possible, just as it is normal that, given the difficult circumstances in which they are locked, they end up perceiving that this is the social contract they have signed with the state. It is impossible to throw stones at such teachers when we rely so much on them for everything. Rather, we may serenely admit that it is probably inevitable that a fair part of planned educational interventions can only be persuasive, and we believe that very good teachers, when the circumstances require it, and to the benefit of all, know how and when to be persuasive.

We must however admit that even a superficial analysis of persuasive teaching leads us to find troubling similarities with commercial, political, and religious discourse, which also seek to produce adhesion, by means of an accumulation of messages, proofs and arguments that are always positive, that support, seduce, hammer, and sometimes use threats and fear. As with selling, ideological submission and faith, teaching can be dogmatic.

In this way, it should not be surprising, under the circumstances, that students have difficulty perceiving the difference between scientific and non- or pseudo-scientific discourse. How indeed could we differentiate science from those things if they credibility in established in an undifferentiated fashion?

Persuasive teaching also encounters another difficulty: that of competing ideological adhesions. If for example a teacher perceives at some point that his or her job is to get orthodox students – or of any confession - to adhere to the theory of evolution by natural selection, how can he or she then simultaneously succeed in the teaching project, while ensuring respect for dogmatic beliefs? How can he or she avoid the moral problem that then arises? How can he or she reconcile the ambition to educate with the "steamroller" aspect of teaching initiatives that focuses on obtaining mere adherences?

The belief in the superiority of science cannot, indeed, suffice to justify a decision and motivation to teach it. However, if one chooses to base one's thinking on science' nature and properties, it becomes possible to see how it differs from other available systems of thought and thus how it constitutes a genuinely additional string to the intellectual bow.

CONVINCING TEACHING

Scientific knowledge is the precise opposite of dogma, just like science is the opposite of dogmatism. As the only enterprise that corrects itself, science's epistemology seems to recognize somewhat of a masochistic character in it. Paradoxically, it is this attitude that gives it robustness, credibility, evolution and actualization. What best resists "self-destructive" assaults would thus be what is "most true" (Popper, 1995). Among the authors of the citations who perhaps best recognize this distinctive character of scientific activity in relation to other types of activity, we recognize some of the greatest:

Having to decide on rejecting one paradigm is always synonymous to deciding on accepting another, and the judgment that results from this decision involves a comparison of the two paradigms with respect to nature and also of one with respect to the other. (Kuhn, 1962, p.115)

A theory that is not refutable by any conceivable event is devoid of scientific character. For theories, irrefutability is not (as is often imagined) a virtue, but a defect. (Popper, De Launay and De Launay, 1985, p.64)

We are trying to prove ourselves wrong as quickly as possible, because only in such a manner can we find progress. (Feynman, Cox, & Ma, 2015, p.67)

It is when a concept changes its meaning that it makes the most sense. It is then that it is -in all truth- an event of conceptualization. (Bachelard, 1963, p.56)

In this context, to adhere "scientifically" cannot be a simple matter of voluntary or enthusiastic adhesion, no matter how constructive it may be. It would rather be to understand why a so-called scientific proposition would or would not be preferable to another competing one, or why it would have some value in relation to a norm or a criterion that are greater than ourselves. To adhere to the scientific way would mean having authentically lived to understand why such methodology, such technique, or such instrumentation are advantageous in comparison with others available. In other words, one must try to establish the value of scientific propositions not only on the basis of personal and absolute opinions, nor even by accumulation of demonstrations of power, but necessarily in relation to an object, an event or even an argument, that are external to deliberating subjects. This is objectivity. Therefore, it appears obligatory to know in what way such or such a proposition would have some relative or utilitarian value with regard to explain and predict events that happen in the world. A teacher helps to establish this value when he or she presents the respective merits and limits of not only Darwin's model, but also of Lamarck's; when he or she discusses with his or her students the reasons why spontaneous ideas are all initially admissible, and then weights and contrasts them with each other and with the models to be taught; when he or she discusses the criterion of simplicity (or falsifiability or reproducibility) of certain scientific propositions; when cognitive biases are evoked in class to explain resistance and adherence; when he or she tolerates errors and makes them a pedagogically interesting object; when talking about scientific knowledge as reductions, and when discussing predictability power, etc.

This approach will be of interest to the teacher who comes up against the religious beliefs of his or her students: he or she is no longer obliged to make the programmed scientific propositions triumph over all other adherences. He or she can talk more broadly about adherences or beliefs, while insisting of the multiple types of arguments that can be mobilized to motivate adherence. Some of them are based on reason (scientific ones), while others can come from elsewhere. It thus could suffice to show the functional or epistemological value of brought forward propositions, to contrast the explanatory, predictive or exploitative, or even comforting powers of the ones to be learned, with the ones of other propositions. He or she can also explicitly attribute the credibility of certain scientific propositions to something other than his or her own action or personal adhesions, such as to the continuous task of scientific communities of systematically putting all propositions to the test. And the teacher can talk about the virtues and limits of trust in scientific institutions.

Obviously, at the end, we must recognize that the only entities that are able to recognize- and credit value to- propositions, scientific or not, are the people who study or examine them, in other words, the learners. Here we come back to the subjective nature of scientific activity, and when people discuss together about the link that could exist between ideas and objects or events, in other words, the facts, we may think

that we have the best possible objective approximation (that is, a scientific deliberative community). In the latter, privileged activities are publication, debate, or conferences, through which and in which scientists meet and try to convince each other of the value of their respective proposals with respect to facts. Trying to convince then appears as an inescapable and deeply scientific enterprise and that is why we should try to adapt this idea in teaching efforts.

In the context of science education, convincing teaching could then be conceived as any teaching that seeks to provide the information and experiences that will lead the learner towards recognizing by himself the relative value of programmed scientific propositions.

This requirement that the learner gets to be convicted by him-/herself is essential. This does not mean that he/she does all the construction work by him-/herself, but that the adhesion is ultimately, at the end of the process, at least partially deliberated upon and that the relative credibility is voluntarily granted by the learner's own intelligence. Obviously, one can wish for more than this minimum, and even for the intelligence to engage much more intensively, interactively, and resolutely in the process of recognizing the value of programmed propositions, or even for the learners to take most of the responsibility in exploring the respective relative credibility of propositions (often obtained by more or less systematically conducted comparative studies).

However, here's one thing: students do not always choose to study science. Thus, reaching such ambitious objectives can be difficult. However, starting with small steps might suffice for some, even if our ambitions for them are obviously greater in the long run, but a minimum of intellectual participation by students in the recognition of the relative value of propositions will at least ensure that the teaching is not only persuasive.

Convincing teaching initiatives can easily be recognized (Table 2).

TABLE 2
CHARACTERIZATION OF CONVINCING INTERVENTIONS

Intervention	Target goals
Teachers and students do not perceive errors as mistakes to be corrected, but rather as resources for better learning (Astolfi, 1997).	To test the value of propositions relative to personal propositions.
The initial conceptions of the students are systematically addressed (Duit and Treagust, 2003) and attempts are made to change them through the dynamics of refutation, comparison, etc.	To test the value of propositions in relation to common understandings.
Attention is paid to the added value of scientific content, and some are favored over others, depending on this value (Potvin, 2018).	Ensuring that high value learning is secured.
Emphasis is placed on historical discoveries, but especially on the contexts of theoretical rivalry that were at their origin (Thouin, 2004) and in which these discoveries proved to be more fertile than those that preceded them.	To test the value of propositions in relation to propositions from the historical past.

Intervention	Target goals
Recognition of the deliberative nature of the attribution of scientific credibility and end up simulating debates according to this manner of doing things (Bell, 2004). Learners are also encouraged to question scientific propositions and to imagine (and develop?) arguments, actions or devices that could attempt to refute them.	To understand, experiment and test the mechanisms for attributing scientific credibility. To encourage student participation in these mechanisms.
Students are given the opportunity to test all sorts of hypotheses and alternative avenues of systematic exploration of phenomena in a relatively autonomous manner (Hasni, Belletête and Potvin, 2018), if possible, up to the point of presenting their chosen approach and results to their peers with the aim of convincing them on this basis.	To understand, experiment and test the mechanisms for attributing scientific credibility. To encourage student participation in these mechanisms.
We explicitly question why we sometimes resist believing certain things (psychology); how we learn better (metacognition) or what the criteria make a particular piece of knowledge be considered as being better than another (epistemology).	To understand, experiment and test the contingencies and obstacles (of all kinds) to the attribution of scientific credibility.
Efforts are made to create the need for scientific knowledge to be taught.	To capitalize on the explanatory, predictive or exploitative value of the propositions to be learned.

We recognize here that several pedagogical proposals which are often presented as innovative or desirable in science, such as investigative approaches, could be qualified as "convincing." Perhaps this is because our dichotomy is based on values or characteristics that are often found in these "fashionable" pedagogical proposals. Or perhaps it is simply a matter of a kinship that stems from the fact that all these activities which are considered sophisticated are easily recognized, consciously or not, by educational researchers as being more in line with scientific activity. However, if they often promote some kind of "conviction," they are not necessarily centered on it and could cultivate other goals. While some clearly could, they would certainly not all deserve to be reduced to this label.

On the other hand, the concept of convincing teaching could possibly contribute to the characterization of these pedagogical initiatives as an adjective rather than a referent and could perhaps be simply contrasted with more *persuasive* pedagogies. Our proposed dichotomy might therefore remain useful in some research and training contexts, but it might especially provide avenues for improving the scientific character of interventions. The questions to which we seek a positive answer are then:

Does planned educational activity provide information and experiences that minimally allow

- to "put to the test," and not only to prove, conceptual or methodological proposals that diverge from the programs' contents, in addition to those that are included in them?
- to reflect on the possibly objective value of scientific propositions according to epistemic standards? Common personal reactions (psychological biases, metacognitive reflections)? Or other constraints related to the value of propositions?
- for learners to attribute by themselves the relative credibility of the scientific propositions being considered?

At the end of this description, let us once again recognize that persuasive teaching cannot, and should not be seen as undesirable. It is, in fact, quite necessary to a teacher who must cover his or her entire program, but when a little or a lot of moral or temporal space becomes available in a teacher's professional life, the ideal of convincing teaching could be seen as a desirable didactic development avenue, because it is clear and likely to improve the scientific nature- and therefore the quality- of educational interventions in science. In this sense, the proposal is not only functional for the researcher, but also for the practitioner. We must, however, recognize that, in reality, the persuasive and the convincing register in tension, although we are often compelled to merely choose. At least, let us do so consciously.

CONTRIBUTIONS AND PROSPECTS

Our proposal is essentially aimed at promoting a more functional labelling of educational interventions that are used in science. A first goal would be to support, through a simple and dichotomous but value-evoking framework, comparative experimental and quasi-experimental studies that test interventions, with an option that we believe is interesting and based on the nature and properties exclusive to scientific activity. It is envisaged that a better identification or a more precise description of compared treatments, which could result from our proposal, would make it possible to better appreciate the nature of the fundamental differences that often exist between considered groups, a better identification of independent variables, and therefore, the precise cause of the effects that could have been recorded, when applicable. Since the credibility of educational research is still to be established with professional consumers of research, we believe that our proposal is a contribution.

We could also hope that teachers' training, both initial and continuous (in-service), could avoid certain excesses by explicitly referring to our suggestion of dichotomy, rather than using vague ones, which could be angelic, infantilizing, and hurtful. Teacher training offers an interesting framework to educators who wish that their teaching will truly promote the development of the scientific spirit. Even though the current social order or, sometimes, their state programs encourage them towards persuasive teaching, many teachers had already implicitly felt that "teaching the results of science is never scientific teaching" (Bachelard, 1967) and had wanted to go further. They often are offered rather vague horizons, which can sometimes be a bit void of any clear qualification criteria for considered interventions. They have also been repeatedly required to "revolutionize their practice," which they obviously will not do on such bases. But perhaps with clear images, simple criteria, and the possibility of gradually transforming their actions, they will be able to do what health professionals apparently succeed at and make their profession evolve.

Here, the proposed key is not only pedagogical; it is didactic, and therefore probably more likely to appeal to science teachers. Out of caution, we have refused to extend it to other school disciplines, which sometimes, as in languages, teach human conventions more than natural phenomena. Perhaps we could be so bold as to suggest that it could also be used in the teaching of the humanities, where sensitivity to historical and social realities is as strong as in science.

For the moment, the value of the proposed dichotomy is only a hypothesis, but we believe that it could also be the object of a comprehensive research program that would set out to test its effects on all sorts of perceptual and academic variables. Although many ideas for the concrete applications of the persuasive-convincing tandem (for specific content and skills) come to mind and seem necessary to better illustrate what we mean, we may need to postpone it to a future contribution.

Finally, we foresee that it is possible and probably necessary, for the sake of coherence, to import the binomial into teacher training, not only for its objects, but also for the way in which we will choose to operate it. Teachers' training is an endeavor which requires that we do what we preach. It would indeed be quite paradoxical and regrettable if training in convincing teaching were to be conducted in persuasive mode. Food for thoughts for the trainers in charge.

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