Teaching sciences during the 18th century: an education in experiment and reasoning.

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Abstract

In the 18th century, colleges or boarding schools are kept by the Jesuits, the Oratorians or the Brothers of the Christian Schools; they are places of spreading of a scientific and technical culture to train the ruling classes of the Absolute monarchy. The scientific training needs the learning of a scientific method based on experiment and reasoning. When the Jesuit Noël Regnault writes *Les Entretiens physiques d'Ariste et d'Eudoxe*, in fact he drafts passages of his lessons marked by the Jesuit pedagogy: the highlighting of experimental facts, especially in physics, the rigor of reasoning. Rigor and method are important, but the experiment is first; that is a question of questioning the nature, of knowing its secrets; this experimental method is very present in the lessons and in the works of the Jesuit Fathers, but also in the Oratorians. At the end of the century, in a course intended for the training of the Brothers of the Christian Schools, Brother Paschal will insist on the analysis and the synthesis as essential components of any scientific reasoning. We thus end on the scientific emergence of teaching methods in the 18th century. Does it send back to a prescientific culture today disappeared? Has the art to teach the sciences in colleges in the 18th century another interest for an epistemological viewpoint on scientific education today?

Keywords*:* Physics; Colleges; Scientific Education; 18th century; Experiment; reasoning.

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Introduction

This research about the scientific training during the 18th century is situated in France in the Jesuits' and Oratorians' colleges. Firstly, it is necessary to criticize the role of these colleges and of their teachers, in education and scientific dissemination during the 18th century. Voltaire who was their pupil, dedicates them a certain gratitude, even if he takes up an attitude opposed to them, against the *Journal de Trévoux* and covering them with his little objective (and little honest) sarcasms. Boris Noguès writes that a good part of "the Parisian school population is got until 1762 by the Jesuit College" (Noguès 2006, p. 132), that is by the college Louis Le Grand, to the detriment of humanities, which also feel pride nevertheless to receive an aristocratic clientele and to train intellectual elite. Marie-Madeleine Compère insists on the quality of the students who make this college a unique place of training of the future executives of the absolute monarchy, in particular, the military nobility. "The college is so an element of the device by which the king maintains a 'personal' link with his nobility while shaping it for the tasks which wait for the noblemen, to the government or to the Court" (Compère 2002, p. 382). The Jesuits "thus trained against their will great minds of the Enlightenment, of which Voltaire" (Noguès 2006, p. 133); their role as this one of some regents of the colleges of the Faculty of Arts in Paris, was doubtless ambivalent. Between education, including the scientific one, and the Enlightenment, the link is very indirect and uncertain. As for the study of the mathematical and physical Sciences in colleges, according to Father de Dainville, during the 18th century and "in the cycle of the philosophic studies" of Jesuit colleges, the physics enjoys a "sort of superiority" (Dainville 1978, p. 363). General physics involved an education in philosophy of Nature and some classes of particular physics (mechanics, optics, Earth sciences and some elements of natural history). Father de Dainville explains: "The physics so understood is at the same time a philosophy of Nature, a course of cosmography, a treaty of physics itself and notions of chemistry, natural history and physical geography" (Dainville 1978, p. 364). Until 1750, such Physics is still very marked by the problems of Nature philosophy and the teaching varies as the regent who is in charge of it is the more a physicist or the more a philosopher. After 1750, the knowledge acquired in particular physics tends to invade general physics to banish from it the rest of scholasticism: "The physics gets free of the philosophy" (Dainville 1978, p. 365). In 1758, Father Aimé-Henri Paulian proposes a relatively scientific classification of the treated topics in a physics class: principles and laws of the movement, the mechanics, the statics, the hydrostatics, the optics (second edition in 1760). We enter then a modern definition of a physics which begins to get loose from Nature philosophy (still present in Paulian's dictionary) to become at the same time mathematical and experimental (Paulian 1761). Actually, the Dictionary of Father Paulian is a moment of this evolution, it still contains general considerations on objects and principles of the physics and the natural history, but it grants a big part to mathematical and experimental demonstrations.

Under this last point of view, we need to insist very clearly on the contribution of the Jesuits and the Oratorians during the 18th century: numerous experiments are made in class, in colleges; they are redone in public, on diverse occasions. In the year 1711 at College Louis Le Grand, Father de La Maugeraye produced some Hydrogen sulphide or something similar in front of his pupils, the "stench of which" obliges him to make open windows. The physics offices become frequent in Jesuits' colleges as in those of the Oratory; the Brothers of the Christian Schools in Marseille will have even their own in the decade before the Revolution. Further to the impetus given by Lamy, Malebranche, Prestet, Jaquemet, the Oratorians also have numerous valuable scientists, the offices of physics exist in all the Oratorian colleges. The presence of Scholars pulled the purchase of experimental equipment, some supplied libraries, experiments made in class and public demonstrations, and publications. Pierre Costabel described a teaching scientific practice not codified in the Oratory during the 18th century: "The master was more a manager of readings, researches and works, than a professor there teaching ex-cathedra" (Costabel 1964, 81). Here, both important points for scientific education are the experiment done in class and the role of master as manager of readings and researches. The invention of the scientific education so underlines a break with a scholastic education.

As regards the Jesuits, their education in colleges is coupled with a literary and journalistic activity, and sometimes, with an implication in the academic movement and production. Antonella Romano writes: "The participation or the Jesuit non-participation in the academic movement has no uniform nature, neither from the spatial point of view, nor from the chronological point of view" (Romano 2000, p. 388). A great number of Jesuits are however "direct actors of the academic life", "trainers of academicians" (Romano 2000, p. 388) or indirect actors, within the framework of the "Republic of Letters". They are at the same time professors, committed in the academic movement, journals publishers, and authors of numerous articles and books. If, in the 18th century, some Jesuits as Esprit Pézenas are remarkable by this activity integrating education, publications, and a correspondence with the Royal Academy of Sciences, others have a real but more limited scientific activity (by their collaboration to the *Journal des Savants* or to the *Mémoires de Trévoux*, for example). However, the hostility to the Jesuits keeps increasing until their eviction in 1762. The company seems remaining present in the academic thought, but Antonella Romano considers that in the 18th century, it supplies technician researchers and leaves the field of the

innovation to other actors (Romano 2000, p. 403). Personally, I would rather speak about teachers or trainers and diffusers of the knowledge. The Jesuits shine during the 18th century with science dissemination. A link between science education and science dissemination is still current today.

An example in teaching physics, Fathers Regnault and Paulian: from college's classes to dissemination of knowledge.

Jesuits' scientific works, more simply works relative to the observation of Nature, are numerous and well disseminated during the first half of the 18th century. It is quite easy to find some treatises in physics or natural history written by Jesuits who were teaching in colleges at the beginning of 18th century. As Father Bougeant, Father Noël Regnault (1683-1762) was a professor at College Louis Le Grand. His vulgarization works contributed to propagate an interest for physics in France during the 18th century. Father de Dainville remarks an elevation of the formation level in mathematics and physics, as for students than for professors: "Between 1700 and 1762, these linked factors gave an important number of distinguished masters: Fathers de la Maugeraye, Regnault in Paris, Morand in Avignon, André in Caen, Rabuel and Béraud in Lyon, Pézenas in Marseille… They became celebrities and they had a real influence on the development of sciences" (Dainville 1978, p. 360). In fact, according to the lists published by Father de Dainville, mathematician Jesuits at College Louis Le Grand were: Father François de la Maugeraye (from 1705 to 1725), Father Pierre Brumoy (from 1725 to 1734), Father Thaddée de Molony (1734-1735), Father Noël Regnault (1735-1752), Father Jean-Nicolas de Merville (1754-1762). These Jesuits were mathematicians in a common sense; they might occupy also a position in physics during their professional life. They were certainly scientists but they differed from the great scholars of the 17th century because they were not necessarily researchers. In fact, it seems that these celebrities of the early 18th century had essentially a role in pedagogy and dissemination of knowledge. Marie-Madeleine Compère writes that "college's celebrities" among whom she puts Brumoy, are well-known by their par pedagogy more than by their erudition: colleges reach a summit but didn't more much contribute to the scientific progress (Compère 2002, p. 387).

The first edition of the *Entretiens physiques d'Ariste et d'Eudoxe* by Father Regnault, is dated to 1729. The book has been republished 8 times during the 25 following years. The author's idea was to put experiments under a book form; these experiments were made in class or in public demonstrations and they corresponded to "curiosities". These experiments and demonstrations try to underline some against-intuitive aspects of the scientific results experimentally acquired. Eudoxe experiments and Ariste explains them. As in Father Bougeant's works, the text is very vast and includes practically all the rising experimental sciences in the period. The text contains very important epistemological remarks on the place of the experiment and method in science (Regnault 1732).

As the *Spectacle de la Nature* (Pluche), the *Entretiens physiques* (physics interviews) give the meaning of a mechanistic nature but they also signify a technical utility of the mechanism. The first volume is completely dedicated to questions of physics in the sense of Science of the moving body; it seems that Regnault wished to give here the beginning of a physics class, such as done for the time in the Jesuit colleges. "Physics is clearly the science of bodies" says Eudoxe (Regnault 1732, p. 8). It involves the shape and the material, which is extended. From this assertion follows a whole description of the infinite small size of some bodies and their very high number in the visible material. This admiration to the small size of the ultimate inseparable is a leit motiv during the first half of the 18th century. The first volume approaches especially the essential characteristics of the bodies from a physical viewpoint, the existence of the material and the space and the laws of the movement and the shocks. In this first volume, we have a compilation of the qualitative knowledge in physics, by 1730, without real concern of mathematical formalization, while this formalization was in progress during this time, as it comes out of the works of the marquise du Châtelet or those of specialists of mechanics by 1730-1750. Let us note simply some points approached by the author with regard to the laws of nature.

Regnault rather subtly envisages the physical body, in an attempt to reconcile Aristotelianism and Cartesianism. Physical bodies are endowed with the capacity of movement and rest. This conception of the moved body comes from the Aristotelian inheritance. However, there the influence of the philosopher stops. Even if there was some opposition

between Malebranche and the Jesuits on diverse matters, here it seems that his physical thought on movement is present. More simply, the book is influenced by Descartes to whom Regnault explicitly refers, despite of the interdictions to teach Cartesianism, renewed without success among the Jesuits during the 18th century. The motion is printed in the body by "the Author of Nature", but the meeting of a "particular cause" is going to determine the transition from the motion to the rest, or the opposite. Let us replace "particular" by "occasional", we find the thought of Malebranche: God prints in bodies the motion following laws that he has himself given and he follows himself. The movement is modified by occasional causes. Regnault writes: "The Author of Nature (…) conserves the body in the same state till a particular cause determines and conserves it in another state. Simple and immutable, He made simple, constant, uniform laws which have the characters of his attributes and he follows them" (Regnault 1732, p. 101).

As in the works of Malebranche, the conservation of momentum (inertial measurement) is replaced in a theological perspective. Then, two questions are approached: the trajectory of a moving body and the relationship between the trajectory and the composition of the strengths applying to a moving body. On this subject, the author gives the example of the wings of a windmill; he decomposes the strengths applied to the wings and he reports the circular movement. Various movements are described: the parabola describing a thrown and falling body explains a movement in which the direction is always changing, a ball obliquely thrown is bouncing on a plan. "The oblique movement of the ball consists of two directions, the one parallel, and the other one perpendicular in the plan. The plan being impenetrable in the ball and set directly against the perpendicular direction in bottom, it changes it in a perpendicular direction in top" (Regnault 1732, p. 115). These considerations on the movement of a body and the "impressions" which condition it are very educational; the author highlights the experience of the physical movement for a human observer. He considers also the questions of the resistance of the environment (air, water) and these of the communication of the movement. Geometry of the movement in the space seems acquired and corresponds to plausible explanations, the composition of strengths is understood as determining a trajectory but the quantitative notions expressing physical magnitudes do not still emerge from this physics remaining very descriptive. The used paradigm remains rather Cartesian.

During the 10th interview, Regnault considers the laws of the shocks, which do not cause any more problems in 1729. He gives practically a speech about the diverse cases that may settle; the proportionality of speeds with regard to the masses is understood but we note the unfit employment of the word "strength". Thus, Regnault writes: "a moved body which moves a body in the rest gives it some strength in proportion both masses" (Regnault 1732, p. 147). A body meeting another resting one shares "this momentum in proportion both masses" (Regnault 1732, p. 148). Laws of the shock of the hard bodies are thus known and taught; the elasticity of bodies puts more difficulties. Regnault evokes this strength of the "spring bodies" which store all the momentum of the body striking them (Regnault 1732, p. 154). Reading these lines on the diverse rules and the scenario applying to the shocks of the hard, elastic or soft bodies, we understand all the echo of the heated debates which took place a few decades previously; we recognize also the educational intention of the author. Have we to deal with a book of popularization or rather a kind of textbook used by pupils or students for the physics class? The second hypothesis seems just to me, especially as the author taught the physics at College Louis Le Grand without excluding the first one. However, the intention exceeds the pedagogy and we see very well in this book what occurs by 1730: we put the presupposition of a God, Author of the Nature, who impulses the movement and settles everything according to laws that he follows himself. What remains to do is to continue the discovery of these laws and to describe the diversity of application cases, with the understanding that they are unchanging. We notice here that in the book, when Regnault describes the multiple cases of the shocks and the movement of bodies, he does not speak about God's role but he considers how the bodies follow these rules.

Even if according to Regnault, we have to go back to the action of a Creator and to discover how He acts, it will be less and less obvious for everybody as we shall progress in the 18th century: this is exactly revealing of the movement of thought occurring at this time. The order move from God's world to the world of physical Nature. If God established himself an order of the world, taking place imperturbably according to laws that seem eternal, then this order is a question of understanding and of describing, until this order will seem as coherent as we shall need no more God to report it. The successive chapters approach diverse aspects of physics in connection with questions that arise at this time, so are approached the magnetization, the gravity, the liquids

and the hydrostatics. The method is the same, very descriptive and sometimes aspiring to the exhaustiveness, close to experiment. The educational purpose is to highlight poorly known physical phenomena and to illustrate them by some experiments. This development of the observed phenomenon is interesting for science education.

The first edition of *The former origin of the new Physics*, dates to 1734. This work is in a way the continuation of the *Physical Interviews*. Ariste and Eudoxe correspond by letters and try to build a history of the physics putting in continuity the Ancients and the Moderns. We shall find the same insistence on observation and experiment with a focus on the history of physics too. According to Father de Dainville, it is doubtless necessary to see there an image of the physics teaching which is set up in the 18th century at the Jesuits and which makes a wide place for the history of the discipline. "The physics teaching is not only scientific, experimental or mathematical, or both together but it aims to be historic, in the sense that it explains the general and particular systems of the authors" (Dainville 1978, p. 370). This trend increases in time, estimates François de Dainville; Father Paulian in 1761, in his *Dictionary of Physics*, will insist on "the critical history of the physicists who appeared until us" (Paulian 1761).

From the beginning of *The former origin of the new Physics*, Ariste describes the stay in country to attract Eudoxe there: "Sometimes, you would believe that the dawn hurries to appear from the evening. Sometimes, the thunder is rumbling: but as the thunder frightens us only for a moment, the physicists know how to discern this formidable moment; this noise, which spreads the terror everywhere, causes them not much alarm" (Regnault 1734, p. 4). Gaston Bachelard spoke about this terror caused by the lightning and the thunder during the 18th century. He emphasized the link between the ignorance of the phenomenon and the fear; he also underlined the nature of a prescientific mind which observed phenomena badly isolated by everyday life, to discover the causes by basing itself on the character of anomaly of these phenomena and their incidence on life in society. So, he exactly identified of what consists a look still marked by a "prescientific" mind (Bachelard 1938). This is exactly what we have here, in Regnault's text, as in the *Curious Observations* of Bougeant and Grozelier: the "science" which is in question, bases itself on many observations on anomalies, physical or biological facts that are out of the ordinary more or less. The social reach or the echo of such discovery is at stake. The observation is rooted in everyday life and the scientific fact is still badly isolated, even if, Regnault is going to show that to observe the scientific fact is the spring of the modern physics. Indeed, we read in the text on the new physics: "Previously, I perceived only the outside of things. Now, I may penetrate into their intimacy; I am admitted in the mysteries. I saw a magnificent show: but I ignored the springs that made play machines, to give me this show. I discover finally springs; and the knowledge of these springs affects me as much as the show" (Regnault 1734, p. 5). The knowledge of the intimacy of the "machine" supposes to understand the mechanism. But we remain here in a global, cosmological vision, and the text quickly bounces on the admiration to the mode of action of a global Nature. Regnault admires for example how Nature begins there "to produce in animals which have no reason, movements which Reason conceives hardly" (Regnault 1734, p. 6). We think of Malebranche for whom the animal life was reduced to the movement, the movement itself depending on God. Let us not make a mistake there: this Nature is not Nature seen by philosophers yet, this is Nature as an object of observations, supposed to lead an apologetic approach. "Such observations lead pleasantly my spirit up to the Author of Nature" (Regnault 1734, p. 7). We know what are worth such assertions, but we find them even written by an erudite Jesuit, 1730s are turned to apologetics.

Father Henri-Aimé Paulian (1722-1801) was a Jesuit and he taught physics in Aix-en-Provence and in Avignon. Grandson of a Protestant minister, Henri-Aimé Paulian was born in Nîmes in 1722. Paulian spread and popularized the conceptions of Descartes and Newton, he is even the author of a Peace Treaty between Descartes and Newton. His major work is the *Dictionary physics*, (the *portable dictionary of physics*, first edition in 1758) which will know eight editions until 1781-1787 (Paulian 1761; eighth edition in 5 volumes). In this last edition, he will contribute to spread Montgolfier's experiments and discoveries in terms of air navigation. This dictionary was the most popular and one of the most read at the end of the 18th century. Paulian was left in Avignon by the eviction of Jesuits from the college, what arrived only in 1768, when Louis XV occupied the city which was until then papal territory; as many Jesuits, Paulian went into the diocesan clergy and thus became "abbé Paulian". He dedicated his life to education and to the publication of physics works; but he went back to an active ministry during the Revolution, risking his life and he died in 1801 in Mauduel, near Nîmes (Pérennès 1851, 284-285).

François de Dainville writes about the Jesuits of Avignon and Marseille: "These men been in love of method opened from 1740 until the abolition of the order in 1763, the greatest shine of our Mediterranean centers for science. (…) Better, [Father Morand] makes build a new observatory (…). We find the echo of some of the observations he made it through articles of the *Dictionary of physics* (1758) of his colleague P. Paulian, physicist at the same college. This work 'well connected and matched with the ruling physics of Newton', of which Voltaire will write that it is 'what has been written of more instructive on the physics for a long time', brings the elements of an outstandingly informed picture about the sciences of this period. The astronomy has its place there. Copernic is avenged: his system is taught as the one that explains best all the phenomena (t. I; p. 199)" (Dainville 1948, 297-298)

Father Paulian was the object of violent criticisms on behalf of the encyclopaedists who maybe saw in him a kind of competitor, and especially on behalf of Voltaire. It seems that the anticlerical spite of Voltaire completely darkens his sense of objectivity and makes him slander the works of physics of Father Paulian; however, objectively, the dictionary of Paulian is not very good and some articles remain simplistic in consideration of the science in 18th century. We read in a letter of January 1764, in *the literary, philosophic and critical correspondence of Grimm and Diderot*: "Paulian, a Jesuit of Avignon, who has already made some compilations, has just published, in three volumes, a peace treaty between Descartes and Newton (Paulian 1763), with the life of these two illustrious philosophers. The title, content and form of this work, are very worthy of a monk; but Descartes and Newton did not deserve such a mediator, and certainly they did not give him full powers" (Grimm and Diderot 1829). This comment was attacking the person and the form of a work without understanding what could be right in this educational intention. Further to the publication of the *Dictionary of physics*, in March 1762, Voltaire spreads in slanders: "Another Jesuit called Paulian, in Avignon, made print a *Dictionary of physics* in three volumes in-4°. Never a Jesuit will make a good work, neither of physics, nor of philosophy. The monastic spirit will always oppose any great and deep view in sciences. The Jesuits in all Europe received their progress only because it was not possible to prevent them. Their first wish would be to banish light and science from Earth; (…) so when you hear that Father Paulian is Jesuit, you know what physics he can teach in his dictionary" (Voltaire 1762, p. 50).

Voltaire seems to have praised moreover successively Paulian and then libeling him as we just saw. It is true that Voltaire wrote this diatribe when the Jesuits were chased away from colleges in France (1762) but it is obviously false that the Jesuits promoted advances in science only "because it was not possible to them to prevent them". It is true that they needed time to assimilate Descartes and the Galilean revolution, as well as the institutional Church; but may we blame them for it? It is inequitable to say that they would want to banish science from Earth and they were useless to Science (Let us think of Father Fabri or Father Pézenas). Certainly, the delay to assimilate Descartes, then Newton, comes from prohibitions to teach such author or book in the colleges, renewed throughout the 17th and the 18th century. We could blame for it the government of the company but not some Jesuit individually.

Conclusion

In the 18th century, intellectual rigor and method were thus important, but the experiment was first to question Nature. Further these experiments, many Christian teachers and researchers focused on the way bodies follow the natural laws: if God established a world order, the question is to understand and to describe this order, which will soon seem as coherent as the Enlightenment will need no more God to explain it. What remains to do is to continue the discovery of these laws and to describe the diversity of application cases, with the understanding that they are unchanging. By 1730, in the Jesuit textbooks, we often find a lack of real concern of mathematical formalization, while this formalization was in progress during this time. From Regnault (1734) to Paulian (1760), we shall find the same insistence on observation and experiment with a focus on the history of physics too. The descriptive method and the insistence on experiment are very characteristic. This approach has set an educational orientation.

In the physics Jesuit textbooks, another problem is still interesting today: the prescientific mind (Bachelard 1938). According to Bachelard, a prescientific mind observes phenomena badly isolated by everyday life, to discover the causes based on the character of anomaly of these phenomena and their incidence on life in society. This is exactly what we have in Regnault's books, as in the *Curious Observations* of Bougeant and Grozelier. The scientific fact is still badly isolated, even if Regnault (1734) is going to show that this isolation of the scientific fact is the spring of the modern physics. At the end of the century, Paulian popularized the conceptions of Descartes and Newton. In the last edition of his major work (the *Dictionary of Physics*), he will contribute to promote Montgolfier's experiments and discoveries in terms of air navigation. This dictionary was the most popular and

one of the most read book at the end of the 18th century. Therefore, in spite of a delay to assimilate Descartes, then Newton, the Jesuit pedagogy based on experiment, understanding of the scientific fact and a beginning of formalization, contributed to science education in France during the 18th century. In spite of a prescientific mentality at this time, these ideas are still important today. At the end of the century (1787), in a course intended for the training of the Brothers of the Christian Schools, Brother Paschal will insist on analysis and synthesis as essential components of any scientific reasoning. The art to teach sciences in colleges during the 18th century still seems having an interest for an epistemological thought on scientific education today.

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