

MATHEMATICS: THE ART OF LEARNING

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Abstract: Much was said throughout the 20th century about the need to change school education. Since the beginning of the 21st century, however, a movement has been gaining strength that aims to go beyond mere change in school education (“mere change” being attempts to reform single aspects schooling, such as curriculum, methodology, use of technology, evaluation, etc.) and promote, instead, innovative, transformative change in education as such (including the education that, still for a long time, will continue to take place through schooling). Advocacy and promotion of Student-Centered Learning, Active Learning Methodologies, Problem-Based Learning, Project-Based Learning, etc. are positive and laudable initiatives in this context. But these initiatives run the risk of being swallowed up by the prevailing paradigm in the area of school education, which is centered on content delivery by the instructor through teaching. For these initiatives to produce their full impact, a new educational paradigm is required, one that focuses on innovative, transformative change in our educational practices. As I searched for a new paradigm, I came across a curious development... I found out that Jan Amos Comenius, considered the father of “Didactics”, the “Art of Teaching”, also proposed, at the end of his life, in a work that was published posthumously, an alternative paradigm: “Mathematics”, the “Art of Learning”. This was more than 300 years ago. Very little attention was given to Comenius’ more mature proposal. I found out in Seymour Papert, however, some heroic attempts to rescue Comenius’ proposal and make it the center of his efforts to revolutionize education through the use of technology not as “teaching machines”, but as “learning tools” that can help students construct their own skills, competencies and knowledge. In more than one of his books Papert insisted that our education, including our school education, be focused on learning rather than on teaching, on mathematics, rather than didactics. In my presentation I will try to spell out the myriad of implications (some of them quite practical and urgent) of this rich and daring proposal of an innovative new paradigm for education, brought to light by Comenius in 1680 and rescued by Papert in the last decades of the 20th century: The Mathematics Paradigm.

Introduction

A movement toward innovation in education has become notorious worldwide. Whatever the reasons for this notoriety (and many are invoked), the fact is that innovative experiences in school education, which some time ago were episodic, happen today literally by the hundreds.

During the 20th century, educational experiences that were disruptive of conventional educational practice, because they were based on alternative theoretical frameworks, could be

counted in the fingers of one hand. The three most important ones, in my view, were the *Summerhill School* (1921, England, A. S. Neill); the *Sudbury Valley School* (1968, United States, D. Greenberg); and the so-called *Bridge School / Escola da Ponte* (1976, Portugal, J. Pacheco). Well over 55 years were needed (1921-1976) for these three major references to become widely known.

More recently, however, already in the 21st century, in the Brazilian city of São Paulo alone, three other experiences of the same nature appeared in the span of only five years: the *Lumiar School* (2003), the *Municipal School Amorim Lima* (2005), and the *Municipal School Campos Salles* (2007).

In 2015 the Brazilian Ministry of Education (MEC) launched an initiative called *Innovation and Creativity in Education*, intended to map innovative experiences in Basic Education throughout the country. From the 683 institutions that submitted their reports, 178 were selected by the evaluation committee, since they complied with the criteria of innovation that had been specified by the Ministry.

Each of these experiences has peculiarities that make it interestingly **unique**. But seeking to understand what they all have **in common** is quite challenging.

Identifying a common thread in these **innovative experiences** is no easy task. Some initiatives assert that they pursue a democratic education. Others prefer to see themselves as pursuing a libertarian education - which, presumably, is not the same thing. Few, if any, admit pursuing a classical liberal (*laissez faire*) education (in the style of Rousseau's *Émile*). But many contend that they stand for diversity, for social justice, against socioeconomic inequality, etc. With regard to curriculum, some of the initiatives come from schools that are part of a network of schools, all of which must follow the same curriculum - something that seems to go against the pledge to innovation. Some understand curriculum as a matrix or mosaic of competencies and skills, rather than a grid of disciplines. Still others, perhaps touching the limit, defend the total absence of prescribed curricula, the students being the only ones responsible for building their own learning itineraries on the basis of their talents and interests.

If we move from the initiatives themselves to their **theoretical frameworks**, the task is no less complex and difficult. They favor different aspects of the process of innovation (pedagogical, psychological, sociological, philosophical, in this case epistemological or ethical) and often end up classifying practical initiatives in different pigeon-holes, thus underlining their

differences, instead of what they have in common and that would justify grouping them all as innovative.

It was as part of a search for a theoretical framework able to identify similarities in the diverse experiences in the area of educational innovation that this research began. In my search for a theoretical framework of this kind I was lucky to come across **two authors** that became fundamental to what I intended to do: **Jan Amos Comenius** e **Seymour Papert**. Curiously, the first was a 17th-century Protestant Moravian bishop who was also an educator; the other, a 20th-century South African mathematician who, likewise, was an educator.

Comenius lived in the region that today is the Eastern part of the Czech Republic. He was the author of the one great reference work of modern education in the 17th century: *Didactica Magna - The Great Didactic*. Because of this work he came to be known as "The Father of Didactics" - Didactics being, of course, "The Art of Teaching".

Didactica Magna was written **to create and establish an educational paradigm** - although the expression was not current in Comenius' time. He wanted his book "to lay the foundation of the universal art [method] of founding universal schools". Here is the full passage, taken from the "Greeting to the Reader" that prefaced his work:

We venture to promise a GREAT DIDACTIC, that is to say, *the whole art of teaching all things to all men*, and indeed *of teaching them with certainty*, so that the result cannot fail to follow; further, *of teaching them pleasantly*, that is to say, without annoyance or aversion on the part of teacher or pupil, but rather with the greatest enjoyment for both further, *of teaching them thoroughly*, not superficially or showily, but in such a manner as to lead to true knowledge, to gentle morals, and to the deepest piety. Lastly, we wish to prove all this *a priori*, that is to say, from the unalterable nature of the matter itself, drawing off, as from a living source, the constant flowing runlets, and bringing them together again into one concentrated stream, *that we may lay the foundation of the universal art of founding universal schools*. [Italics added.] (Comenius, 1907, p. 5).

The educational paradigm proposed by Comenius - "*the whole art [method] of teaching all things to all men . . . with certainty . . . pleasantly . . . [and] . . . thoroughly*" - was welcomed by the schools of his time (and ours), who tried to do exactly what he recommended: to teach everything to everyone. For these schools, *education is encyclopedic and has to do with teaching* - the "pleasurable" part they left out.

Didactics

It was Comenius who used the term "Didactics" for the first time in the context of modern school education. The word, however, is old, existing already in classical Greek, exactly with the meaning of *The Art of Teaching*.

Comenius' *opus magnum* seems to be at the root of the reason why, today, in school education, **everything turns around teaching**. Schools are *Institutions for* [or: *of*] *Teaching*. In order to work there, professionals must take courses in *Didactics* or the *Methodology of* [or: *for*] *Teaching* different things (subject matters, disciplines, etc.). In these courses they become proficient to elaborating *Teaching Plans* that will make use of *Teaching Resources* and instruments for *Student Evaluation* (in this case, to see if students absorbed what they were taught). Schools are supposed to become a hierarchical *System of Teaching*, structured in different levels: *Elementary Teaching, Fundamental Teaching, Basic Teaching, Intermediary / Middle Teaching, Higher Teaching, Graduate Teaching, Post-Graduate Teaching...* In all of this, teaching is overseen by *Teaching Inspectors, Teaching Coordinators, Teaching Supervisors*, etc. who work for *Teaching Secretariats* or *Teaching Ministries...* In this context, when people speak of innovation, they mean *Teaching Innovations* that should maintain and guarantee *Teaching Quality*.

It is true that sometimes other terms are employed do refer to these things or activities: Education, Instruction, Formation. But they are all meant to imply **Teaching**. The modern school is a teaching institution. **Nowhere**, in the above huge list of labels, is there a single reference to **Learning**.

This is symptomatic of an **important problem**. Any serious concept of Education must admit that **Education necessarily implies Learning** (not Teaching!). Nobody can be considered educated if they have never learned anything! People may have stayed eighteen years in more than one school, and there they may have been taught a ton of things there, BUT, if they have not learned anything there, they have not been educated in these schools. The situation is even worse than that: if they have learned a few things in the process, but these things have nothing to do with their lives, with what they want to be and do in life, they have not been educated. The issue is as simple as that.

The **younger Comenius** worked under a **serious delusion**: he thought that, if you teach it (whatever "it" may be), they (the students) will learn it (the same "it" that was taught). Under this assumption, if you **teach** them **everything**, they are sure to **learn everything**, including whatever is necessary for them to live successful (happy, accomplished) lives.

The **older Comenius** (as we will see) realized in time that he suffered from a delusion. His realization came from two basic considerations:

- (a) People can be taught an enormous amount of things and not learn much - as a matter of fact, not learn anything that was taught, not to mention anything that was relevant for them to live successful lives, that actualize their life projects (as, today, the majority of the school population of a country like Brazil can prove);
- (b) People can learn an enormous amount of things, and among them, perhaps, the most important things in life, without being taught them (such as: to recognize the faces and voices of their parents, siblings and close relatives; to realize that some sounds have meanings and associate these meanings to the corresponding sounds; to master language as an instrument of communication and a tool for labelling and identifying concepts; to stand, balance their body and move themselves on their two legs; to read and write; etc.).

Education has to do with learning, not with teaching! Its major objective (no matter how it is specified) has to do with learning. If teaching (or anything else) produces learning, then it can be part of education; if it does not, it is no part of education.

That is the lesson Comenius learned late in life.

Teaching and Learning

The mere enunciation of this thesis produces a high level of discomfort and stress in contemporary educators. That is because they think like the younger Comenius. They have been convinced that their task is to teach, and that, if they teach well, students will learn. They like to think that if they do that, they will have done all that could be expected of them.

Some educators (theoretical or practical) would like to think that teaching and learning are part of a single phenomenon or process that contains two elements: *teaching-learning* (the two terms hyphenized, this linguistic decision supposedly implying that the two things are "fused" in reality!).

This "fusion" of teaching and learning results from mental "confusion".

The problem is that, as Comenius realized late in his life, teaching does not necessarily imply learning, and learning does not necessarily require teaching (i.e., has teaching as a pre-requisite). It is as simple as that. That was clearly demonstrated (among others) by Eduardo

Chaves, forty years ago (Chaves, 1979, pp. 118, 127), but many others have not had any doubt about this fact for centuries - including the older Comenius.

The school is an institution created and maintained so that people (especially, but not exclusively, young people) can learn things - things that are important to them (or, in last resort, to their family or to the community in which they live). There was a time when it was thought that the only way people would learn was by being taught. Today we know that this is not true. And, ironically, we owe this recognition to the same person who is considered the father of "The Art of Teaching".

Chaves' main argument in the aforementioned article is that it is an undeniable fact that **teaching can be successful as well as unsuccessful**. Successful teaching is teaching that produces the intended or desired learning - something that, indeed, can happen when the content of the teaching is something that the would-be learner is interested in and when the teacher knows the subject well, is also interested in it (still better: passionate about it), and is able to present what needs to be learned in an easy-to-follow manner. Everything else, I am inclined to say, is unsuccessful teaching, because it will hardly bring about any learning related to what was taught (or even any relevant learning outcome whatsoever).

Sometimes the reason why teaching is unsuccessful does not have to do with any failure in the teaching itself, but only with the fact that the would-be learner has no interest whatsoever in what is being taught. This explains, in part, why some students stay for several years in some Brazilian public schools, without learning how to read and write (at least not the things that the schools want them to read and write).

If we leave the context of the school and the classroom, it is evident that people learn innumerable things through experience, observation, discovery, trial and error, and, especially, through intentional exchanges of information and know-how in horizontal (*peer-to-peer*) interaction and dialogue. This is the way people learn, outside the school, most of what they know, and most of what they know how to do, even when they are totally illiterate.

Bernard Charlot, of the University Paris VIII, once said in a talk he gave in São Paulo:

The business of the teacher is not to teach - it is to get the student to learn. The definition of teacher is not 'one who teaches', but 'one who helps a student learn'. To teach is not the same thing as to get a student to learn - even if, many times, in order to get a student to learn, the teacher must teach (Charlot, 2002, p. 96).

Charlot confirms the thesis that teaching and learning are two clearly distinct processes, and makes it clear that the teacher must be focused on student learning, not on his own teaching,

since teaching is only useful and thus justified when it helps produce learning in the students (more specifically, the intended or desired learning).

Roger Cousinet also makes the distinction between teaching and learning explicit when he states (in a book originally written in 1950) that:

The new education consists in replacing the teaching of the teacher by the learning of the student. The student does not go to school to be taught, that is, to be the passive object of the didactic activity of an adult. The student goes to school to learn what it means to be the subject of their own learning activity (Cousinet, 1976, p. 7).

Those who assert the "fusion" of teaching and learning often make the following "confusion": they consider teaching and learning to be analogous to selling and buying. In this case, it is correct to say that one can only buy something if somebody else is selling it, and that someone only sold something if somebody else bought it. But it is a serious mistake to apply this principle, through analogy, to teaching and learning. The mistake consists in considering knowledge, or competence, or whatever is the object of learning, as a "thing" (maybe a "commodity") that, being external to those involved in the relationship, can somehow be "delivered" by one, the teacher, and "received" by the other, the student.

That it is a mistake to think this way was shown by Piaget and Vigotsky. Knowledge, according to them, and the same may be said of competencies and other things that can or must be the object of learning, is something that is **actively built or constructed internally by the subject**, through interaction with the object of learning itself **and** with other people in a social context. If Piaget and Vigotsky are correct, and I am convinced that they are, the analogy between teaching and learning, on the one hand, and selling and buying, on the other, is inadmissible. Knowledge, in their view, is not an external thing that can be delivered and received, or, still less, that having been received can be absorbed and assimilated either by the mind or the body of the receiver. Knowledge, in their view, is built or constructed internally, by the student/learner, with or without the help of a teacher (but hardly without any social interaction whatsoever). To think otherwise is to adopt the banking analogy used by Paulo Freire, which is quite similar to the selling and buying analogy: instead of selling, depositing; instead of buying, withdrawing the funds deposited.

Seymour Papert, however, **went a little beyond** in his analysis of teaching and learning. Here is what he says:

In the context of a School-dominated society, the most important principle of mathematics may be the incitement to revolt against accepted wisdom that comes from knowing *you can learn without being taught and often learn better when taught least*. [Italics added.] (Papert, 1992, p. 141).

Papert suggests that teaching and learning not only are distinct and independent processes, but that, occasionally (though more frequently than one would wish), teaching stands in the way of learning and either prevents it altogether or makes it more difficult and cumbersome. This happens for a rather simple and clear reason. In teaching, the teacher is the protagonist; in learning, it is the student who must be the protagonist. It is not hard to conclude that, while protagonism lies with the teacher, who is intent on teaching, there will be neither time nor space for student protagonism, intent on learning. Teaching and learning can, thus, in Papert's view, compete against each other, and even become antagonical to each other!

It is on the basis of this double recognition, namely:

- (a) that teaching and learning are two clearly distinct processes, which occasionally interact and intersect, but ought never to be confused, much less "fused"; and
- (b) that, in education, learning is the essential process, and therefore ought to be the focus;

that we ought to define the role of the teacher and of the school in learning and, *a fortiori*, in education.

It is in this context that the concept of "Mathetics" and what I intend to call the "Mathetical Paradigm" fit.

Spicilegium Didacticum

Mathetics, as an innovative pedagogical paradigm, appeared with Comenius, who, besides being "The Father of Didactics", must also be acknowledged as "The Father of Mathetics".

When Comenius published *Didactica Magna* in 1657, he was already aware that there was a clear distinction between teaching and learning, and insisted on it, and also made it clear that his goal is student learning. In the presentation of his book he states:

*Let the main object of this, our Didactic, be as follows: To seek and to find a method of instruction, by which teachers may **teach less**, but learners may **learn more**; by which schools may be the scene of less noise, aversion, and useless labour, but of more leisure, enjoyment and solid progress.* [Italics in the original; bold added.] (Comenius, 1907, p. 4).

In the first place, when he proposes that teachers teach less in order that students learn more, Comenius shows that teaching and learning are distinct processes that even may take one in *opposite directions* (less teaching implying more learning). In the second place, he shows that he had in mind a school that was not meeting the *learning* needs of the students, the environment of which was not pleasant (since it was noisy, tedious, demanding work that was useless, etc.) - and that seems similar to the environment of many contemporary schools. He wanted schools to become attractive learning environments, where students could concentrate more on their learning tasks and make more solid progress in their learning objectives or itineraries. *Didactica Magna* is proposed, therefore, as a contribution to help students learn more, better, and more pleasurably, and **Comenius intended this to happen through less, not more, teaching.**

However, he unfortunately did not succeed in his undertaking. There are at least two indications of his failure.

First, and most obvious, the intended outcome of his project did not come about - and has not come about even up to the present day, despite all the changes through which society and schools went through in these period of almost 350 years.

Second, in 1680, twenty-three years after the publication of *Didactica Magna*, and ten years after Comenius' death, a posthumous work of his was published, called *Spicilegium Didacticum*. This little-known booklet was published by Christian Václav Nigrin and is considered the very last work by the Moravian bishop. The original is available today in the Dutch National Library, which received it from the University of Groningen (Groninga).

Spicilegium is a Latin word that, literally, refers to the corn cobs that, for whatever reason, are left behind in the field after a first harvest. In a figurative sense, *Spicilegium* represents a collection of items or ideas which, having been available for use or application in a first moment, were, for one reason or another, neglected, and, now, later on, are found and presented again, in the hope that this time they may do the work to which they were intended to do all along.

In the case of *Spicilegium Didacticum*, the items or ideas left behind were concepts and suggestions contained in the original *Didactica Magna* which, for one reason or another, were not put to good use, and that, in the author's view, deserved another chance...

Spicilegium Didacticum indicates that, after the publication of *Didactica Magna*, Comenius was alert to the fact some concepts and suggestions presented in that book were

neglected by those who adopted his *opus magnum* as reference. Compiled, they came to 56 pages, divided in only two chapters.

The first chapter, with 38 pages, had the title *Mathetics*. The second, with only 16 pages, had the title of *Didactics*. The structure of the booklet and the number of pages dedicated to one and the other topic show that, in the author's view, *Mathetics* had been the main neglected element.

On the basis of these two indications, the hypothesis suggests itself that the main reason for Comenius' failure was the fact that his readers, and the users of his book, opted to concentrate their efforts on the teaching of teachers, not on the learning of students, on *Didactics* rather than on *Mathetics*, probably because Comenius himself was operating under a delusion (already mentioned) when he wrote and published his major work - delusion noticeable in the title (which emphasized Didactics and, therefore, teaching) and in the goal of helping teachers teach everything to everyone.

It was this delusion that he tried to shed in the *Spicilegium*.

Mathetics

Mathetés (μαθητής), in Greek, means apprentice, pupil, disciple, learner (one who learns). *Mathetêia* or *máthema* (μαθημα) is that which one (a *mathethés*) learns.

The term "Mathetics" was officially used in the sense of "The Art of Learning" at least beginning with the publication of *Spicilegium Didacticum* in 1680, in an effort to rescue elements which Comenius thought were important for education but that were not receiving due attention since the publication of *Didactica Magna* 23 years before.

But it was Seymour Papert the one responsible for resurrecting the concept at the end of the twentieth century, in 1980, exactly three hundred years after it was used by Comenius in *Spicilegium Didacticum*.

Papert, who died in 2016, brought important contributions to education, especially through his LOGO Project, sometimes referred to as *Turtle Geometry*. The programming language he and his team invented, apparently involved, in a first moment, only the use of the computer to help children learn geometry. (The cursor used in the software of the programming language had a cursor in the shape of a small turtle, hence the expression *Turtle Geometry*). But it quickly evolved into a powerful learning tool for problem solving and, through problem solving, for learning basically anything.

In his 1980 book Papert defines "Mathetics" as "the set of guiding principles that govern learning" (Papert, 1980, p. 52). In his 1993 book, Papert develops in more depth, and in a more systematic form, these guiding principles that govern learning.

Some Principles of Mathetics

Among the many principles that Papert discovered or devised, and which he considers "**Principles of Mathetics**", a few are particularly relevant in the context of educational innovation.

First, a combination, into a single principle, of two of Papert's important preferential emphases: **Construction** (over against Reception and Absorption) and **Concreteness** (over against Abstractness). This principle specifies, on the one hand, that *learning has to do primarily with constructing things* (**not** with *being informed about things* or *getting to know things*, important as these things may be), and, on the other hand, that *the things constructed should preferentially be real physical things in the material world* (**not** mental things, such as schemata, models, theories, concepts, etc. important as these things may also be).

The "constructing" element reflects the fact that Papert worked with Piaget in Geneva for several years and so was totally familiar with Piaget's Constructivism. The preference for "concreteness" over abstractness resulted in the important partnership between LOGO and LEGO and on Papert's subsequent emphasis on the importance of robotics for learning.

Conventional schools (exception made to professional or vocational schools) do not, as a rule, leave time and space for constructing things (instead of absorbing information), much less for constructing physical things (instead of mental objects).

Second, Heuristics, a principle that can be described as *the art of finding solutions for real problems*. It is through Heuristics that active methodologies such as Problem-Based Learning, Project-Based Learning, Inquiry-Based Learning, etc. became part of Mathetics, since they give the students excellent opportunities to effectively solve real problems in the world, through learning projects of their interest.

Again, few conventional schools give emphasis to these methodologies, since these schools concentrate their priorities on giving the students ready answers, instead of helping them find the answers themselves through projects that investigate possible solutions to problems they consider important, either from a personal point of view, or, alternatively, from the standpoint of the community or society in which they live.

Third, *Connexionism*, which emphasizes the fact that learning takes place best when learners are able to connect what they are trying to learn with things they already know. It is important, therefore, during the learning process, to look for links with other things one already knows or even with other areas of inquiry. Transdisciplinary problems increase the possibility of these links, since these problems go beyond the artificial divisions that often "unlink" connections which exist in reality - doing this for the sake of disciplinary boundaries.

Once more, most regular schools offer the students fragmented disciplines, which are fragmented even more by the way school time is divided and allotted to different subject matters, disciplines, topics, issues, problems, etc. in school setting.

Fourth, *Utility (Usefulness) and Pleasure (Fun)*, which specifies that *the things we learn, in life and in school, ought to be either useful or fun*. Learning takes place in more meaningful and effective ways when that which one is learning has one of these two characteristics: it is useful for doing things we want or need to do, or it is fun, in and of itself. When it has both, the results are still better. Later in life Papert developed the notion of "Serious Fun": how to do serious things and have fun at the same time.

Useful things are tools; fun things are toys. Mathematics has to do with learning to construct and use tools and toys. In both cases, the learning that ensues is pleasurable and brings joy and contentment to the learner.

Conclusion

When people learn, they bring to their learning tasks their different talents and interests, which form unique configurations. **This fact must be respected.** The fact that it hardly is respected in conventional schools explains much of their failure. That is why Mathematics defends the existence of personalized learning environments in which each and every learner has freedom to learn what is important to them, because they are interested in it, like to do it, and do it well. This means that freedom and personalization go together and are an integral part of Mathematics.

Quality education based on the principles of Mathematics must be:

- Learner-centered (not teacher-oriented);
- Diverse, flexible and personalized, not standardized, one size fits all;
- Focused on inquiry-led problem-solving;
- Geared toward transdisciplinary issues related to the interests of the learners;

- Based on active and constructive methodologies;
- Anchored on the useful and the pleasurable (tools and toys).

It is past the hour to leave behind the one-size-fits-all school.

When we aim at quality education, it is not enough to have schools for everyone: it is necessary to have a school for each one.

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