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CONSTRUCTIONISM AND THE SHIFTING FROM DIDACTICS TO MATHETICS

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ABSTRACT

In his work *Spicilegium Didacticum*, published in 1680, Comenius discusses mathetics (*Mathetica*, or *ars discendi*) and didactics (*Didactica* or *ars docendi*). But, unlike didactics, which curriculum development placed at the centre of the teacher-student relationship and teacher education elected as one of its essential elements, mathetics has remained almost always implied, as if it were a mere by-product or simply a consequence of didactics. This tradition has been challenged by Seymour Papert, particularly in his major works (1980, 1993, 1996), in which he rehabilitates the importance and the primacy of mathetics by associating it to his pedagogical proposal - the constructionism -, which is a radical extension of Piagetian constructivism brought to the field of pedagogy and involving the use of ICT. This paper, of a theoretical nature, revisits Papert's constructionism, especially as it stresses the need to achieve maximum learning with minimal teaching, which relocates mathetic and heuristic processes to the centre of pedagogical settings

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INTRODUCTION

1. Introduction

In the work *Spicilegium Didacticum*, published in 1680, Comenius attributes the following meanings to *mathetics* and *didactics*: *Mathetica*, or *ars discendi*, is the art of learning to know things or to seek the science of things (p. 1); *Didactica*, or *ars docendi*, is the art of teaching what we know, so that others know the same (p. 26). However, unlike didactics, which curriculum development placed at the centre of the teacher-student relationship and teacher education elected as one of its essential elements, mathetics has remained almost always implied, as if it were a mere by-product or simply consequence of didactics. This tradition, which had already been strongly criticized throughout the twentieth century by pedagogues such as John Dewey and Paulo Freire, for example, was again challenged by Seymour Papert, particularly in his major works (1980, 1993, 1996), in which he rehabilitates the importance and the primacy of mathetics, by associating it to his pedagogical proposal - constructionism -, which is a radical extension of Piagetian constructivism brought to the field of pedagogy and involving the use of ICT.

This proposal advocates, among other things, the need to achieve maximum learning with minimal teaching. Papert's pedagogical proposal, by placing didactics in the background and mathetics and the heuristic processes of apprentices in the centre, challenges the normativity of the curriculum itself, as well as it challenges traditional curricular development, demanding an incomparably greater autonomy for the learner and the redefinition of the role of the teacher, whose action tends to become increasingly peripheral. This paper, of a theoretical nature, discusses Papert's pedagogy as an irreconcilable discontinuity with traditional one, and tries to identify it as a clear example of disruptive pedagogical innovation. The significance of this paper lies on the opportunity to revisit Comenius' almost forgotten definition of mathetics and Papert's appropriation of it as a tool to promote learners' autonomy no matter curricular trends and constraints.

2. Didactics

In the period between 1450 and 1650, words such as syllabus, class, curriculum, subject matter, didactics, which we still associate with school and curriculum (Hamilton, 1992) were included in the European educational lexicon.

But it was in 1576 that, according to Doll Jr. (2002), the word curriculum appeared for the first time associated with a sequential course of study in *Professio Regia*, written by the protestant Petrus Ramus, in a time marked by the Renaissance and the Reformation, two of fundamental impulses toward modernity. In the earlier period of Scholasticism, the main focus of the disciple's activity was the deepening of philosophy, which corresponded almost to the totality of knowledge. This deepening implied the attempt to reconcile faith and reason through the Dialectic, having as sources the texts of the ancient philosophers and the Fathers of the Church, besides the Sacred Scriptures and, as a purpose, to seek the confirmation of dogmas through Logic and Of Dialectics. The disciple, having full access to the whole of the texts, delivered to himself or under the guidance of a tutor, sought to free himself from the contradictions that could divert his reasoning, until arriving at the interpretation provided for by the canon. In turn, the curriculum was concerned with selecting what should be taught to the student and how to make accessible what would be taught to him through organization and simplification, which consisted of replacing the Dialectic by Didactics and the text by the textbook, which, as Hamilton (1992, p 8) noted:

... is not merely a compendium of knowledge. Rather, it is an assemblage of knowledge organised for educational purposes. Textbooks, therefore, are not simply depositories of knowledge. Through their chapters, headings, tables, illustrations, worked examples, homework exercises, and so on, they mediate the structure of knowledge on the one hand, and the performance of teaching and learning on the other. They are a condensation, therefore, of both knowledge and instruction.

Thus, in addition to determining what was to be taught, the curriculum, through didactics and its main instrument, the textbook, began to determine also how to teach. And five centuries of curriculum, whose evolution throughout the century XIX was deeply marked by the factory school and by the simultaneous instruction, followed by the Taylorization, made sure that didactics, despite its often repeated preoccupation with learning, in fact, never stopped putting the teacher and his activity in the centre of events, staying the student on the periphery.

3. Mathetics

Not always, however, the focus on didactics was so exclusive.

In the third paragraph of his monumental *Didactica Magna* or Treaty of the Universal Art of Teaching All to Everybody, Comenius clarified its purpose by stating that

The bow and stern of our Didactics will be to investigate and discover the method by which teachers teach less and students learn more; in schools, there is less noise, less boredom, less useless work, and, on the contrary, there is more recollection, more attractive and more solid progress; In Christianity, there is less darkness, less confusion, less dissent, and more light, more order, more peace, and more tranquillity[1].

However, in order for teachers to teach less and students learn more, it was necessary to take care of their activities, so the development of the art of teaching (all to everybody) was not the only goal of Comenius, who devoted much of his last work, *Spicilegium Didacticum*, to Mathetics, defining it, as opposed to didactics, as the art of the student (*Mathetica est ars discendi*), which consists of the task of learning to know things and seek the science of things. And it is this idea of mathetics, as the art of learning, and as an activity of the apprentice, which is taken up again by Seymour Papert in his seminal Mindstorms, where he presents it as being for learning as the heuristic for solving problems and stating that Its principles are ideas that illuminate and facilitate the learning process. In this work, published three hundred years after the publication of *Spicilegium Didacticum*, Papert speaks of metaphors used by mathematically sophisticated adults to illustrate his idea that, in addition to giving little emphasis to learning, it means different things inside and outside of school:

Mathetically sophisticated adults use certain metaphors to talk about important learning experiences. They talk about getting to know an idea, exploring an area of knowledge, and acquiring sensitivity to distinctions that seemed ungraspably subtle just a little while ago. I believe that these descriptions apply very accurately to the way children learn. But when I asked students in grade schools to talk about learning, they used a very different kind of language, referring mainly to facts they had learned and skills they had acquired. It seems very clear that school gives students a particular model of learning; I believe it does this not only through its way of talking but also through its practices (Papert, 1980, p 136).

The first is the mathetic meaning of learning, allow the pleonasm. The second is its "didactic" meaning, that is, what the school, which has specialized in didactics, leaving in parentheses the mathetics, thinks about learning. Papert returns to the discussion on mathetics in his next book. From The Children's Machine (1993), I have selected four passages which I find particularly eloquent. The first has to do with how time is different, when viewed from the point of view of mathetics or didactics:

Give yourself time is an absurdly obvious principle that falls equally under heuristics and mathetics. Yet School flagrantly contravenes it by its ways of chopping time: "Get out your books ... do ten problems at the end of chapter 18 . . . DONG . . . there's the bell, close the books." Imagine a business executive, or a brain surgeon, or a scientist who had to work to such a fragmented schedule. (p. 89)

The second has to do with the clarification of one of the fundamental principles of mathetics, according to which a good discussion promotes learning and with the antimathetic nature of the culture we live in, of which the school is an integral part:

A central tenet of mathetics is that good discussion promotes learning, and one of its central research goals is to elucidate the kinds of discussion that do most good and the kinds of circumstances that favor such discussions. Yet in most circles talking about what really goes on in our minds is blocked by taboos as firm as those that inhibited Victorians from expressing their sexual fantasies. These taboos are encouraged by School, but go far beyond it, and point to ways in which our general culture is profoundly "antimathetic." (p. 89).

The third relates constructivism and mathetics, in that it recognizes that the learner does best when he searches, studies,

[1] From the Portuguese translation by Joaquim Ferreira Gomes. Retrieved from http://www.ebooksbrasil.org/eLibris/didaticamagna.html.

investigates the knowledge he needs. And that the knowledge children most need is what helps them gain more knowledge:

Traditional education codifies what it thinks citizens need to know and sets out to feed children this "fish." Constructionism is built on the assumption that children will do best by finding ("fishing") for themselves the specific knowledge they need; organized or informal education can help most by making sure they are supported morally, psychologically, materially, and intellectually in their efforts. The kind of knowledge children most need is the knowledge that will help them get more knowledge. This is why we need to develop mathetics. Of course, in addition to knowledge about fishing, it is as well to have good fishing lines, which is why we need computers, and to know the location of rich waters, which is why we need to develop a large range of mathetically rich activities or "microworlds." (p. 139)

The fourth is an acknowledgment that the most important principle of mathetics, in a society dominated by didactics, is the incitement to revolt against readymade "wisdom", knowing that one can learn without being taught and that everyone can learn better when less taught:

In the context of a School-dominated society, the most important principle of mathetics may be the incitement to revolt against accepted wisdom that comes from knowing you can learn without being taught and often learn best when taught least. (p. 141)

4. The leading actor and the supporting actors

The word mathetics, for Comenius as for Papert, carries an identical sense that has been lost along the time in the school and the culture. It recognizes the learner as protagonist of his learning, while didactics places the teacher at the centre of teaching processes. Mathetics, therefore, does not consist in the pious claim to a "student-centred teaching", which is a material impossibility, whose invocation, just out of the mouth, results from the awareness that schools are normally organized by classes composed of different students (despite the myth of homogeneity), each of them deserving, in principle, a tailor-made teaching centred on his personal characteristics. The problem is that the syllabus is one and also the teacher, and limited the time to teach all students, who also have a previously established common time to show that they have learned what they have been taught. That is why teachers do what they have been educated to and professional experience has also endorsed: in the improbability of truly knowing each student and in the impossibility of planning a lesson for each student, the teacher plans a lesson for all, which is focused on the processes of teaching, that is, in him.

Mathetics belongs to a different logic. It is not a collective process, but an individual one, although social interaction favours it. There is not a mathetic process for all, but an ongoing mathetic process of each one, which begins long before school, since the beginning of cognitive development, which the school, especially the industrial one, anchored as it is in simultaneous instruction, simply cannot recognize. To do so would have to be something else. For example, it could not have a (teaching) curriculum *a priori* and for all, but so many learning "curricula", as much as the apprentices, an idea that, by itself, would definitely shake the very foundations of traditional schooling. Even from the grammatical point of view, the verbs to learn and to teach are of a different nature. To learn is an intransitive verb, while to teach is transitive. Who teach, teaches someone. Who learn, just learns. For this very reason, Papert said that he did not particularly enjoy the word teaching because it seemed too transitive. For mathetics, as will be easily inferred, only works with the learner at the centre of the process, and cannot work otherwise. According to its logic, the activity that counts is the activity of the one who learns, much more than that of the one who teaches, even if it does so according to the constructionist prescription of trying to induce the maximum learning with the minimum of teaching, which can "kill" the apprentice if it is not used in homeopathic doses. Despite rhetoric, students are invariably at the periphery of didactic processes, while teachers are invariably at the periphery of mathetic ones. In the centre, there can only be room for the one who stars. And it was thinking of this dialectic between mathetics and didactics that I wrote:

To put it another way, this innovative teacher, if he were running for the Oscars of education, would be a candidate for best supporting actor, while the apprentice would be the natural candidate for best lead actor (Fino, 2008, p 2).

However, the relation between mathetics and didactics cannot be a dialogue between equal forces, at least in the light of constructionism, whose assumptions are based on mathetics. As a result, the constructionist teacher has to work many more times in the periphery than in the centre, in spite of it is difficult for him to act appropriately in this position for cultural reasons.

5. Mathetics and pedagogical innovation

In a more recent article, Hamilton also addresses the equivalent meaning of didactics and pedagogy correspondingly used within Continental European and Anglo-American cultures:

By contrast, pedagogics is not an alien notion to Anglo-American educationalists. It re-entered the Anglo-American educational lexicon after 1970, having lain dormant since the First World War (cf. Cruikshank, 1998). The 1970s revival, however, was not a restatement of earlier assumptions. Rather, fresh meanings arose that, paradoxically, have hindered transatlantic dialogue. The European discourse of didactics is, I suggest, very close to the Anglo-American discourse of pedagogics. Only their language divides them. (Hamilton, 1999, p 135).

This enlightenment helps to even better comprehend Papert's insistence in mathetics rather than didactics, as mathetics is a concept much closer to the Continental European meaning of pedagogy, which is much broader and was not fully captured by the current meaning of didactics. I am aware, of course, that there are those who believe and affirm that didactics and pedagogy is the same and that there are those who confuse the words education, teaching, pedagogy and didactics. And there are people who consider that mathetics, if it exists, is a mere part of the didactics. Moreover, there is no doubt that didactics has, in fact, much greater notoriety than pedagogy or mathetics in the global culture, which Papert, as I have mentioned, considers anti-mathetic. And the last few years, at least in my country, have not been very favourable, neither to the terminological precision nor to the consideration of elements that are not deemed to be essential, such as grades,

accountability and so forth. Of all the expressions that common sense normally associates with the school, the one that has more value in the Continental European part of the "market" is didactics, without doubt, as can be seen by the legislation on teacher education, which gives to didactics a huge prominence when compared to the other components. On the other hand, years of unbridled anti-*eduquês*[2] propaganda, which led his champion to become minister of education from 2011 to 2015, added clearly pejorative connotations to everything that could evoke preoccupation with the nature of learners, especially recent theories about cognitive development, such as constructivism, for example. At the same time, the act of teaching is from long ago understood as a purely technical act, both by politics and common sense, or often internalized by the teachers themselves: the teacher is the technician who masters the techniques to teach, being these techniques codified according to the principles of didactics. The teacher is the technician who develops the curriculum, according to the didactic presuppositions of curriculum development.

In this environment, mathetics can hardly be considered as the crucial thing that should be. The problem is that the processes of pedagogical innovation, without which the school and its industrial procedures will remain trapped in the nineteenth century, have very little to do with didactics and its techniques of planning and transmission, however sophisticated they may be. The pedagogical innovation passes exclusively through mathetics, which implies the autonomy of the learner and the redefinition of the role of the teacher, with all the consequences of this migration of the learner, from the periphery to the centre of the processes of action and construction.

6. Constructionism as an example of emphasizing mathetics

Those who are familiar with Papert's work know that his quest was not changing schooling systems, because he always was very aware of the impossibility of changing schools by means of pedagogical change alone. He also knew that teachers were never the force with enough power to transform formal education because he knew that, in the past, a large number of pedagogues raised their voices against the school system very rightly but with little success. Instead, his pedagogy was meant to empower learners with technology, to be used as means to access to knowledge and to manipulate objects of learning, inside or outside the schools, in settings not completely colonized by the curriculum.

6.1. Some roots

Firstly, we have to go back one century to meet some ideas of John Dewey that have strongly influenced Papert's concept of constructionism. From the seminal *Democracy and Education* I have chosen two excerpts as an introduction. In the fifteenth chapter, *Play and Work in the Curriculum*, Dewey argues:

Study of mental life has made evident the fundamental worth of native tendencies to explore, to manipulate tools and materials, to construct, to give expression to joyous emotion, etc. When exercises which are prompted by these instincts are a part of the regular school program, the whole pupil is engaged, the artificial gap between life in school and out is reduced (Dewey, 2001, p 202).

In the same chapter, he added:

Moreover, opportunity for making mistakes is an incidental requirement. Not because mistakes are ever desirable, but because overzeal to select material and appliances which forbid a chance for mistakes to occur, restricts initiative, reduces judgment to a minimum, and compels the use of methods which are so remote from the complex situations of life [...]. It is quite true that children tend to exaggerate their powers of execution and to select projects that are beyond them. But limitation of capacity is one of the things which has to be learned; like other things, it is learned through the experience of consequences (Dewey, 2001, pp 204-205).

These two ideas of Dewey - manipulation of tools and materials to express happy emotions, and the right to error - are strongly rooted in constructivism, as we will see.

6.2. Building things in the world

According to Papert, constructionism is a pedagogy that goes beyond Piagetian constructivism, which looks at the child as a constructor of its cognitive structures, in interaction with the world. Constructionism denies a common belief that the path to better learning involves perfecting instruction. It refuses, therefore, the conviction that the school will be better only because it teaches better. Papert (1993), without denying the value of instruction, recognizes again with Piaget that each act of teaching may deprive an opportunity for discovery. Therefore he suggests that the constructionist attitude towards learning should be minimalist: trying to obtain the maximum of learning from a minimum of teaching. But he warns that this minimalist attitude towards teaching is not enough if everything else (curriculum, etc.) stays as it was.

To put it another way, constructionism requires an attitude inspired by an African proverb about how best to help someone who is hungry: a hypothesis is to give him a fish, but the redemptive hypothesis would be to give him a cane and teach him to fish. In Papert's words:

Traditional education codifies what it thinks citizens need to know and sets out to feed children this "fish." Constructionism is built on the assumption that children will do best by finding ("fishing") for themselves the specific knowledge they need; organized or informal education can help most by making sure they are supported morally, psychologically, materially, and intellectually in their efforts. The kind of knowledge children most need is the knowledge that will help them get more knowledge. This is why we need to develop mathetics. Of course, in addition to knowledge about fishing, it is as well to have good fishing lines, which is why we need computers, and to know the location of rich waters, which is why we need to develop a large range of mathetically rich activities or "microworlds." (Papert, 1993, p 139)

The adverb mathetically has to do with *Mathetica* (mathetics), the Latin word meaning the art of learning, the learners' task that Comenius proposed to be used as opposition to *Didactica* (didactics) which is the classical art of teaching.

[2] *Eduquês* is a Portuguese neologism, which started to be used to designate the whole of the educational jargon, only full understandable by part of the educational community. This word acquired finally a pejorative meaning, designating everything deemed to be evil in the field, especially the "bad" influence of constructivism and other "romantic" theories of learning.

Still discussing constructionism, Papert continues:

Constructionism also has the connotation of "construction set", starting with sets in the literal sense, such as Lego, and extending to include programming languages considered as "sets" from which programs can be made, and kitchens as "sets" from which not only cakes but recipes and forms of mathematics-in-use are constructed. One of my central mathetic tenets is that the construction that takes place "in the head" often happens especially felicitously when it is supported by construction of a more public sort "in the world" - a sand castle or a cake, a Lego house or a corporation, a computer program, a poem, or a theory of the universe. Part of what I mean by "in the world" is that the product can be shown, discussed, examined, probed, and admired. It is out there. (Papert, 1993, p 142)

And he goes further:

Thus, constructionism, my personal reconstruction of constructivism, has as its main feature the fact that it looks more closely than other -isms at the idea of mental construction. It attaches special importance to the role of construction in the world as a support for those in the head, thereby becoming less of a purely mentalist doctrine. It also takes the idea of constructing in the head more seriously by recognizing more than one kind of construction (some of them as far removed from simple building as cultivating a garden), and by asking questions about the methods and the materials used. (pp 142-143)

As can be seen, constructionism strongly emphasizes objects external to its creator, as constructions in the world, which can be shown, discussed, examined, tested and admired. Thus, sharing a creation can result not only in its refinement but also in gaining a deeper understanding of other people's perspectives.

Constructionism - the N word as opposed to the V word - shares constructivism's connotation of learning as a 'building knowledge structures' irrespective of the circumstances of the learning. It then adds that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe... (Papert, 1991, p 1)

As for the underlying theories, Papert gave the following insight in the abstract of a research project[3] he submitted in 1987:

The word constructionism is a mnemonic for two aspects of the theory of science education underlying this project. From constructivist theories of psychology we take a view of learning as a reconstruction rather than a transmission of knowledge. Then we extend the idea of manipulative materials to the idea that learning is most effective when part of an activity the learner experiences as constructing is a meaningful product.

Another element usually associated with constructionism is technology. However, technology being one of the essential elements for the creation of constructionist learning environments is not its most critical element. Constructionism is not a technocentric approach to pedagogy. If we were to identify a centrality to it, it would certainly not be technology, which is mere tool for thinking, but action, construction, and mathetics. To paraphrase Dewey (2001), the centrality of constructivism would be to explore, manipulate tools and materials, build, express joyful emotions.

6.3. Error as an opportunity and no excuse for omission

Constructionism takes up Dewey's idea that the opportunity to make mistakes is a secondary requirement, not because mistakes are always desirable, but because over zeal in the selection of materials and devices that forbid the possibility of error restricts initiative, reduces judgment to the minimum and requires the use of methods that are far from complex life situations. Those who had the opportunity to write computer programs know that the written code does not always correspond to what the programmer intended or expected to happen. Often the first attempts contain bugs. And, in extensive and complex code lists, debugging is a complex and difficult activity. However, in learning based on the right to initiative (children are in charge, as Papert pointed out), it is natural that learning happens through trial and error, where the unexpected response is seen as a positive step in the desired direction. And the learner is encouraged to think about why the unexpected result occurred. Unexpected results are therefore accepted as important and useful steps in the learning process, with debugging being an essential part of this process, through which conceptual frameworks are tested and modified until they are considered appropriate. Thus, bugs are not stigmatized as errors, nor does error mean failure, but only as unexpected results whose occurrence must stimulate thought and understanding.

In addition, and to appease some spirits for whom error, or its consequences are terrible things, in the microworlds supported by technology, the consequences of error are contained within, not causing anything disturbing outside them. Unless we find disturbing the power over the machine and the detachment that allows the cycle described by Valente (2003) of description-execution-reflection-debugging-description, which allows children to deepen their metacognitive abilities and act as truly epistemic beings. Perhaps he would like to ramble a little, citing Stager (1999), when he asserted that the attacks on the Logo language, with rare exceptions, were not fought in the field of ideas, but in the marketplace. Logo was bad for business. If children construct knowledge and express themselves in an environment designed to have no limits, then why acquire quantities of other "educational" software? Schools that do not discontinue old computers because they remain perfect to function as LEGO-Logo workstations do not buy as many new computers every year. That is why, while Software Publishers Association gave Papert a prize for its career, its associated companies conspired to keep Logo language-related products out of educational technology conferencing programs. And that is why the most sinister attacks on the Logo are acts of omission. As Stager (idem) also pointed out, he received for analysis as a teacher educator, numerous compendiums on theory, history, and practice of educational computing, most of which did not disagree with research on the Logo language or the theories of Seymour Papert. They simply did not mention them, ignoring four decades of classroom research and practice, although they allegedly intended to provide a complete analysis of

[3] In https://nsf.gov/awardserch/showAward?AWD_ID=8751190, Retrieved September 20, 2017.

educational computing, which Stager considered unacceptable and intellectually dishonest. At present, by irony, we are witnessing the rehabilitation of the precocious activity of programming driven by the market. It is now called *coding* and it is promoted by the same market that endows technological *start-ups*.

6.4. Curriculum: the huge wall

As Robinson (2011) pointed out, there is today the same hierarchy of disciplines in secondary schools and, increasingly, also in elementary schools of virtually all educational systems modelled on the industrial paradigm. Mathematics, languages and sciences are at the top, then the humanities (history, geography, social studies) and physical education. At the base are the arts, but there is also a hierarchy between them: plastic arts and music generally have a higher status than theatre and dance. In addition, these hierarchies have become one of the central elements of a globalized curricular architecture.

A whole century ago, Dewey (1916) noted that

So far as schools still teach from textbooks and rely upon the principle of authority and acquisition rather than upon that of discovery and inquiry, their methods are Scholastic—minus the logical accuracy and system of Scholasticism at its best. Aside from laxity of method and statement, the only difference is that geographies and histories and botanies and astronomies are now part of the authoritative literature which is to be mastered (Dewey, 1916, pp 288-289). A century later, the wall continues to grow. It is against it that the best pedagogies still stand in the way.

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