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Mathematics education in the neoliberal and corporate curriculum: the case of Brazilian agricultural high schools

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Abstract The pedagogical principle *learning by research* guides the current curriculum in agricultural high schools in Brazil. A problematization of the principle shows how (1) it feeds into current neoliberal and corporate agendas in the education sector, and (2) it associates mathematical formalism and abstraction as necessary conditions for the production and use of biotechnology. Data consists of official national and institutional policy documents, as well as interviews conducted with nine former students, along with their school notebooks and tests. The theoretical and methodological framework draws on the work of Michel Foucault. It is argued that neoliberal market values are embedded in the mathematics education, through the articulation of abstract and formal reasoning with techno-scientific knowledge, for the purpose of competitive production. The *learning by research* principle shapes students' subjectivities to desire becoming techno-scientificized individuals. The ethical question of the subordination of the value of mathematics education to a neoliberal, predominantly marketized logic is raised as a challenge to the role of mathematics in contemporary cultures.

Keywords Mathematics education · High school agricultural education courses · Mathematics in agricultural education · Mathematics education and subjectivation

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1 Setting the scene

Learning by research is the current motto that guides education in agricultural high schools in many places in the world, also when it comes to mathematics as part of their curriculum (Harlin, Roberts, Briers, Mowen, & Edgar, 2007; Parr, Edwards, & Leising, 2008; Stripling & Roberts, 2012a, b, 2013; Wells & Anderson, 2015; Young, Edwards, & Leising, 2009). In Brazil, a country with a large rural population and extensive agroindustry, studies have pointed to the adoption of *leaning by research* as a new pedagogical principle, that promises to bring the future to rural areas (Albuquerque, 2011; Banin, 2012; Giongo & Knijnik, 2016; Nascimento, 2012).

In the 1980s, the Brazilian countryside underwent a modernization with the introduction of new technologies and management practices aligned with a neoliberal market rationality. The modernization included not only the introduction of new agricultural machinery and materials, but also the development of new production techniques (Buainain, Alves, Silveira, & Navarro, 2014; Delgado, 2001). Public policies on agriculture favored mainly medium- and large-sized farms and agro-industrial complexes targeting the foreign market. As a result, inequalities in the rural population were reinforced, privileging the historically ill land distribution in Brazil (Balsan, 2006). These economic and social changes in rural Brazil since the 1960s produced the "conditions of possibilities"—in Foucault's (2002b, p. 265) terms—of agricultural technical education in the country and consequently the emergence of federal agro-technical high schools (Giongo & Knijnik, 2016).

At the beginning of the twenty-first century, the modernization process of the Brazilian countryside suffered a change, aligned with the new configuration of the capitalist economy: The success of agricultural and livestock production began to depend on biotechnological developments, especially in regard to genetically modified organisms (GMOs). Multinationals such as *Company X*[1] took control of the production and sale of GMO seeds and pesticides, among other things, affecting small, medium, and large farmers. Associated with this control, farmers were led to adopt an entrepreneurial attitude with the introduction of business management strategies designed to meet the demands of an international, competitive market economy.

Following the initial modernization and the change toward biotechnology, Brazilian high school agricultural education underwent two main curriculum reforms. The first was guided by the pedagogical principle of "learning by doing", inspired by John Dewey's pragmatic view of knowledge and learning (Toledo, 2016, 2017). The second reform emerged as part of a public education policy enacted during the first Lula Administration[2]: the creation of the *Institutos Federais de Educação, Ciência e Tecnologia* (Federal Institutes of Education, Science and Technology; hereafter, *IFs*). These schools were grounded on a "political intentionality, as a result of the current capitalist social and economic context at the national and international levels, and on the wish to strengthen and expand professional and technological education based on a new organizational model" (IFRS,[3] 2010, p. 10). The principle of *learning by*

[1] For ethical reasons, we use the name *Company X* to refer to a multinational company that is present in most of the Western countries and has traded its products on the world agricultural market since the 1990s (Buainain et al., 2014).

[2] This refers to the first term of president Luis Inacio Lula da Silva, in the years 2004–2008.

[3] In Rio Grande do Sul (RS), the Southernmost state of Brazil, the *IFs* are called IFRS. The study reported here was developed in the IFRS situated in the small town of *Sertão*. Therefore, it will be called *IFRS-Sertão* (Toledo, 2017).

research emerged in this economic context, which is tightly connected with late forms of neoliberalism.[4]

In recent decades, the complex nexus between capitalism, science, and technology brought transformations in the ways individuals conceive life, understand the world, and in particular, produce science. Technology has come to be the origin and end of the production of science—a phenomenon that Latour (1987) called techno-science. In summary, contemporary techno-science represents the intertwining of the production of scientific knowledge, techniques, and capitalism within the current neoliberal form of reason. It is considered that one of the main points to ensure the social and economic progress of society—and of individuals—is the necessity to techno-scientificize the new generations (OECD, 2017). To educate people in this direction is one of the key strategies to overcome this necessity. This is why science and mathematics education are privileged areas of education (Bocassanta & Knijnik, 2016; Silva, 2011). The Brazilian Federal Institutes (*IFs*) were established in order to realize the demand of making neoliberal, techno-scientific subjects.

The case of agricultural high schools and its mathematics education in Brazil is a particularly rich case to explore a topic of concern within the studies of the cultural politics of mathematics education. The taken-for-granted goodness and desirability of mathematics in current global and national discourses to strengthen STEM education has been questioned for its effects on how learners and education gets reduced to their economic dimension (e.g., Carter, 2015; Valero,2016; Valero & Knijnik, 2015). Such tendency puts at stake the very possibility of a common good and of democracy (Brown, 2015). Most of these critiques, however, have fallen short in evidencing how neoliberal subjectivities are produced in and through the workings of mathematics education. This study contributes to existing international research by showing how students' desire to become techno-scientificized individuals—and the achievement of such desire—articulates within the discourse of neoliberal, corporate mathematics education curriculum in technical, agricultural high schools.

The paper starts by presenting key notions that have guided our methodological strategy. Then we unfold an analysis of how the principle *learning by research* articulated in the partnership between agro-business corporations and technical schools. Then we show that the attributed role of mathematics in the curriculum as the subject providing formalism and abstraction acquires a new meaning when the *learning by research* principle operates. Having showed the forms of subjectivity that are offered for students and teachers and pointed to their contingency in the current capitalist order, we conclude challenging the truths that are being built in that particular mathematics education discourse.

2 Theoretical tools and methodological moves

Michel Foucault's notions of discourse, subjectivation, and surface effect are central in this investigation. He considers *discourse* as "those practices that systematically shape the objects they talk about" (Foucault, 2002b, p. 56), and not as "a pure and simple interweaving of things

[4] Broadly discussed in the last two decades, we adhere to a meaning of neoliberalism as "the new political, economic, and social arrangements within society that emphasize market relations, re-tasking the role of the state, and individual responsibility." It can be seen as "an extension of competitive markets into all areas of life" (Springer, Birch, & Macleavy, 2017, p. 2). Furthermore, we align with Brown (2015, p. 17) who defines neoliberalism as a "form of reason that configures all aspects of existence in economic terms".

and words: the dark weave of things, a visible, embodied and colorful chain of words" (Foucault, 2002b, p. 56). In a Foucauldian perspective, discourse is considered in its positivity, involved in the production of truths. This implies that "it plays an important role in subjectivation processes that affect the individual" (Hattge, 2014, p. 31). The truths—constituted by power–knowledge relations—produce what Foucault called "effects of truth" (2012, p. 224). Truths "work" on the individual and on society in such a way that they are taken for granted without any questioning. We are subjectivated by them. To Foucault, discourse and the statements that shape its truths play a major role in the modes of subjectivation, because the latter are "the way in which the relation with oneself, by means of a certain number of techniques, allows constituting oneself as the subject of one's own existence" (Revel, 2008, p. 82).

Furthermore, Foucault invites to the researcher to analyze discourse in its exteriority; that is, to consider "what was said on the surface, without submitting it, for instance, to interpretations of the cause-effect type, which Foucault, inspired by Nietzsche, opposed" (Wanderer & Knijnik, 2014, p. 93). He also directs our attention to identify *surface effects* (Foucault, 2002a):

> There are verbal performances that are identical from the point of view of grammar (vocabulary, syntax, and the language (langue) in general); that are also identical from the point of view of logic (from the point of view of propositional structure, or of the deductive system in which it is placed); but which are enunciatively different. (p. 145)

The field of enunciations in a time and space no "longer has that appearance of a monotonous, endless plain" (Foucault, 2002a, p. 128); on the contrary, these enunciations are part of a system of positivities that produce them and shape the rationality at a given time. In other words, even if statements and truths seem to be the same, "it is not the objects that remain constant, nor the domain that they form; it is not even their point of emergence or their mode of characterization" (Foucault, 2002a, p. 47). Therefore, it becomes important to investigate the network of enunciations that intertwine and provide a new basis for the statements that appear to be similar.

Drawing on the previous points, our methodological design is composed of a set of procedures. Specifically, its data consist of official Brazilian *documents* with *IFs* pedagogical guidelines, as well as *IFRS-Sertão* institutional documents related to its two curricular reforms; interviews performed with nine former students of *IFRS-Sertão*, six of whom ended their studies in the 1980s, and three graduated in the 2010s; and also, institutional *materials* (notebooks and tests used in the mathematics and technical courses when the participants studied in the school).

The interviews were performed individually and did not follow a previously defined script. The participants—men between 19 and 50 years old—were invited to talk about their lives as students, their experiences as learners in the mathematics and the agricultural education courses, and their current professional activities. We paid attention to who they were, how they organized their everyday lives, and their feelings about the role of mathematics education in their school trajectory. Doing so, we followed what Jørgensen and Largarcha-Martinez (2014) highlight about the importance of positioning the interviewees as actors of their own stories. This allowed us to understand how their enunciations emerged, and to identify the forces that were operating in their stories.

In the interviews conducted by the first author, the participants were asked to tell about their learning in the high school agricultural education. A "prompting question" was asked (Souza, 2015, p. 48): "What are your memories of your agricultural education?" The participants

produced narratives that in most cases were relevant. When necessary, other questions were formulated in order to go further into a specific idea that the interviewer considered be important to attain the study objectives.

Each interview lasted approximately two and a half hours. They took place in the participant's home or at his workplace. Before starting the interview, the purposes of the study were explained, as well as the ethical stance toward the production and socialization of data. After due authorization, each interview was taped and fully transcribed. The preliminary analysis indicated that it would be useful to have a second meeting with four of the participants since some points of their interviews were not sufficiently clear.

One of the interviewees brought to the second meeting a box containing his old notebooks and tests and also magazines and manuals used during his time as a student. Some of them were used during the conversation, mainly to explore aspects of the mathematics and the technical courses. This became a good strategy to recall classroom situations that brought new and relevant data to the study. Therefore, the strategy was repeated with the three other participants. The participants received the transcript of the first and second interviews. They were asked to read them and add or delete anything they wanted.

We performed a discourse analysis as framed by Foucault (2002a, b), following the ideas explained above. No judgments of value regarding the pedagogical guidelines presented in the documents or the pedagogical practices described were produced on our side, since this attitude would compromise the analytic exercise that we wanted to undertake (Wanderer & Knijnik, 2014). In the official documents, institutional materials and participants' interviews, we identified recurrent enunciations about what is important and what characterizes agricultural education. From these recurrences, there emerged different statements that are discussed in the following sections.

3 *Learning by research* and the techno-scientifization of agricultural education

The curriculum at the Brazilian Federal Institutes such as *IFRS-Sertão* and, specifically, in its high school agricultural education program, is based on the principle of *learning by research.* It is rooted on the conception that "science is the part of knowledge that is best systematized and expressed by concepts [...] that help human beings to reflect on concrete reality" (IFRS, 2010, p. 24). Technology is "understood as the appropriate science for productive ends" (2010, p. 24). One of the objectives of agricultural education consists of teaching the students to "plan, manage, control, and implement technical-scientific activities in the field of agriculture and livestock" (IFRS, 2011, p. 11). The curriculum should articulate "the notions of work, culture, science, and technology, taking into account a perspective of totality, synthesis of multiple relations, without a dichotomy between general and specific knowledge" (IFRS, 2010, p. 23). This articulation must be present "in the pedagogical proposals, in the curriculum organization, and in the flexibilization of school and out-of-school times and spaces" (IFRS, 2010, p. 20).

In these official documents quoted above, there is an implicit conception of research, science, and technology associated to the *learning by research* principle. The interviewees clearly indicated that curricular practices developed at *IFRS-Sertão*, for instance, sought to determine "the efficiency of the fungicide, whether there is resistance or not", "the safety of applying pesticides, or using new varieties of seeds", and so on. For putting this clearly into practice, agro-business companies were associated to the activities at the institution. For example, the internships that are part of the curriculum took mainly place at different agro-

businesses. In particular, *Company X*'s research—the one already developed or the one underway concerning new machinery, genetically modified seeds and agricultural pesticides—was disseminated as part of the activities at the school. *Company X* is the main protagonist of the relationship between *IF*s and corporations, even if this is not explicit in the institutional documents (Buainain et al., 2014).

Company X exercised a strict commercial oversight, but this control was considered appropriate:

> There are invoices, registration, everything is recorded, there is no way to get away from them [from *Company X*]. Nobody manages to avoid paying; even if they buy from their neighbor, they inspect everything. The guys from *Company X* control everything. (Interviewee 2)

This excerpt indicates that *Company X* operates with surveillance and regulation mechanisms (Foucault, 1980), acting on each farmer and consequently on all those involved directly or indirectly with the cultivation, commercialization, and consumption of food produced using genetically modified seeds. Farmers get convinced of the company's importance for their success in agricultural production. As two of the interviewees said:

> Transgenics are very good for farmers, really very good. In terms of public health, nothing has been proved as to whether it is good or not. (Interviewee 1)
> *Company X* has revolutionized the world; they increase production on a high scale, the production of foods needed by the world in large amounts. (Interviewee 8)

The interviewees also said that the highest profits for the farmers come from the use of GMO, that is, from the adoption of biotechnology in their production. It should also be observed that economic interests, characteristic of the prevailing form of capitalism, are placed above the logic of other forms of production such as environmentally-aware and sustainable organic farming, or above other aspects of human life, such as the preservation of health in the population. The interviewees explicitly pointed that:

> Before transgenics, herbicides, insecticides, and other products were used. So the difference now is the glyphosate. But does glyphosate harm more or less than other products? (Interviewee 2)
> Now I ask you […]. What about Coca-Cola? Pollution? How many medicines do you take? I cannot see anything bad in transgenics. [...] Knowing what I do about biochemistry, about plant physiology, about the physiology of people, I really think that I cannot see what harm is caused by transgenics. There are no tests that really prove this harm. Can chemical products interfere in human health? They can, but sometimes we use the same molecule to treat the flu [...]. (Interviewee 8)

The farmers do not question that the (high) cost of the new technologies developed by *Company X* is being passed on to them:

> And we pay a lot for this. [...] We buy the seeds, we pay for this technology which is expensive. There is no way to compete in the market. Whoever does not choose the technology does not get ahead, and *Company X* began a long time ago and brought us farmers many good things […] we have to pay royalties on our production to *Company X*, this is a percentage on the technology that they sold us [...]. (Interviewee 1)

Recurrently, the interviewees stated that their professional qualifications and consequent entry into the market were directly related to the most recent high school agricultural education at *IFRS* curriculum reformulations, which includes the use of new technologies:

> Today agriculture is a very dynamic process. There is a lot of research, a lot of technology transfer, a lot of technology being implemented, [...] and the technicians must be constantly updating their knowledge. […] That is the only way that I'll be able to meet the labor market demands as an agricultural technician [...]. The agriculture and livestock sector has changed a lot in the last few decades; we have tripled productivity, we must invest in new ideas and research is the key point for this. (Interviewee 8)

This excerpt explicitly states that the pedagogical principle *learning by research*, based on biotechnology, allows the students to deal with the changes that have occurred in the agriculture and livestock sectors in the last few decades. Thus, it may provide greater profits to the farmer and consequently favor his entry and ability to keep up in the currently competitive agricultural market. Indeed, as mentioned by the participants, "one cannot even think about [...] competing in the market if one does not have technology on the [rural] property" because "the damage caused, for instance by caterpillars [...] is much greater than the cost of technology." Competing in the market "is difficult [...] without these technologies, it is very difficult [...]. These are all new technologies brought by the researchers who are there."

These educational practices, taking place in State-funded schools, in close relationship with commercial and corporate interests worked as subjectivation processes on students—who will work in agroindustry—and teachers. Through the education in the *IF*s, everyone becomes subjected to the order of the GMO's discourse. Consequently, the insertion and permanence of biotechnology in the national and worldwide agricultural production and markets, characterized by competitiveness and the ceaseless search for the accumulation of wealth, are reinforced. This leads us to think that the subjection of students and teachers to the logic of the neoliberal market also subjected them to the statements that shape the techno-science discourse.

As a result, it is considered as a taken-for-granted truth that to enter and specially to remain in the game established by the prevailing neoliberal market, the farmer must learn to use the results of the techno-biological research and to be competitive and entrepreneurial. In summary, today the curriculum of high school agricultural education at *IF*s is ruled by a biotechnological logic. This means that the principle of *learning by research* is constrained to performing experiments linked to biotechnological research. In rural areas, the techno-scientific discourse mobilizes a set of practices that regulate the production of knowledge regarding agriculture and livestock in contemporary times. Even further, the close ties between these practices and the current prevailing neoliberal rationality become clear. Property management and competitiveness become decisive conditions for the farmer to take part in and remain in the neoliberal market. The issue of how mathematics is part of such configuration is addressed in the following section.

4 The reconfiguration of mathematical formalism and abstraction in *learning by research*

Here, we zoom in on the mathematics education discourse that circulates in high school agricultural education at *IFRS-Sertão*. Mathematics education here includes not only what

happens in the courses of mathematics but also in the elements of mathematics which are part of technical courses like bioclimatology, topography, and rural management.

Based on the analysis of institutional documents, specifically those related to the curriculum's pedagogical guidelines and the school mathematics syllabus, we concluded that in the last three decades the syllabus had not changed; it was the same. Based on the analysis of the students' notebooks and the interviews, it also became evident that all content was taught following the same pedagogical procedures. First the concepts were presented, then examples were given, and finally exercises were listed with questions that were similar or even the same as the examples presented by the teacher. Thus, there was a sequence, an order, and a hierarchy in the content to be taught in the mathematics course, as well as a specific pedagogy for instruction. A question emerged: how could it be possible that the syllabus and mathematics teaching practices had not changed if the curriculum in the 1980s was guided by the principle of *learning by doing*, while now it was guided by the *learning by research* principle? Was this perceived sameness some kind of "stability" or a "surface effect" that called for further exploration?

Following Foucault (2014), we conjectured that the practices (and the contents they transmitted), due to their continuous repetition, would have an effect on high school teachers and students. Their ways of thinking and signifying both school mathematics and mathematics itself were—in the time of the *learning by doing* reform—and are—in the time of the *learning by research* reform—conducted in a given direction, which subjects them to the statement: *The mathematics taught must follow the rules of formalism and abstraction* (hereafter called the "key statement").

Walkerdine (1995, p. 225) emphasizes that because the school mathematics grammar is shaped by rules such as formalism and abstraction, one is led to consider that school mathematics has a "logical discourse" that can be applied to everything. She reaffirms this position, indicating that in the 1950s and 1960s, the central idea of mathematics as a reason was "enshrined in the curriculum" (Walkerdine, 2004, p. 116). This was interpreted by many as if "logical mathematics principles" could be used to encode all types of activities. In this way, school mathematics would occupy a privileged place in the school curriculum, which, at least in part, corresponds to the place occupied by academic mathematics in modernity. As a result, other ways of thinking are devalued, since "being rational became conflated with mastering mathematics" (D'Ambrosio, 2011, p. 75).

Foucault argued that positioning the mathematical discourse as "a prototype for the birth and development of all the other sciences" would be to run "the risk of homogenizing all the unique forms of historicity, of reducing to the authority of a single rupture all the different thresholds that a discursive practice may cross" (Foucault, 2002a, p. 189). Mathematics "certainly served as a model for most scientific discourses in their efforts to attain formal rigor and demonstrativity; but for the historian who questions the actual development of the sciences, it is a bad example" (p. 189). When one talks about level of "formalization", the history of mathematics "never ceases to recount about itself in the process of its own development" (p. 189). In regard to "its domain, its methods, the objects that it defines, the language that it employs", mathematics is "never thrown back into the external field of nonscientificity, but is constantly undergoing redefinition" in the formal aspects that constitute it (p. 189). In search "of a more abstract, or more powerful theory, or one existing at a higher level; mathematics retranscribes its real historical trajectory into the vocabulary of vicinities, dependences, subordinations, progressive formalizations, and self-enveloping generalities" (p. 189).

If these are characteristics of school mathematics and of mathematics, it is not surprising that the key statement was and still is part of the school mathematics discourse in high school agricultural education. The apparent "stability" must however be seen as a surface effect. Our attention turned to identify the enunciations that are interwoven with the key statement in each of the periods guided, respectively, by the principles of *learning by doing* and *learning by research*.

Data analysis led us to conclude that, in the past, the key statement was interwoven with the following statement: *Abstract and formal thinking enables the continuation of studies because leads to a higher order thinking that will enable advancing knowledge* (in this case via a higher education course). The excerpts below indicate this:

> But these things of mathematics, formulas, and all these rules to follow develop thinking; they were only for people who were going to college. (Interviewee 2)
> These formulas are not useful to us. They help develop memory, these x, y formulas, they do not have any function, […] that is to activate the mind, activate memory, develop memory […]. I think that was for people who were going to college, and at that time very few people left there and took the entrance exam to university. (Interviewee 1)
> Mathematics was all formulas, but they were only any good for people who were going to enter to university, and since I was not going to, and also did not like [the mathematical formulas], I did not even bother to learn to them. (Interviewee 5)

The research participants considered that formalism and abstraction were tools that allowed them to go further in their studies. Mathematics is important because abstraction and formalism are positioned at the highest level of thought, which is to be achieved in university studies.

In contrast, nowadays the key statement is articulated with another statement: *The training of agricultural technicians should be based on the pedagogical principle of learning by research, which requires formal and abstract thinking.* Here, what is at stake is the direct connection of abstract and formal thinking with the production of scientific and technological knowledge, which is supported by research—in other words, by techno-science. The relevance of mathematics comes from its uses in scientific and technological fields, thanks to its formalism and abstraction.

When the participants were asked to make more explicit the meanings they assigned to the "acquisition of formalism and abstraction", they pointed that this meant to acquire expertise in using formulas. The formulas were supposed to enable implementing the pedagogical principle of *learning by research*. They considered that mathematics was relevant in their training, since, as one of them said, "to do research it is really necessary to know mathematics, deal with software, with Excel, with regression analysis—it [school mathematics] is an 'essential course'".

An agricultural technician (who ended his studies in 2011 and currently attends the higher education agronomy course at *IFR-Sertão*) explained:

> To do research […] you need to have logical mathematics reasoning to understand how it works. Beginning with the size of the sample, to decide how big the experiment will be [...] To do statistical analysis, I need to know mathematics, to calculate the profitability of applying a herbicide or fungicide, I need to know mathematics [...]. In the research I did about strawberries and soybeans, I needed to know mathematics to use the software and interpret the spreadsheets, read the results, and discuss them. [...] Because

> the day I had to know a logarithm to run regression software, that is when I began to see I really need to know mathematics. (Interviewee 8)

Here, we can identify the relevance given by the participant to formalism and abstraction of school mathematics. He considers that there is a need to acquire "logical mathematics reasoning". This requires learning how to think in an abstract way and express this abstraction formally. The pedagogy must lead "to understand how [logical mathematics reasoning] works." Since this pedagogical path is recurrently followed, it "works" on the students' subjectivities.

Popkewitz (2008, 2012) is very clear about this point. Extending to the realm of schooling the discussion about "quantification as a technology of distance" (Popkewitz, 2012, p. 169), he argues that the acquisition of the universal language of mathematics functions as a technology "of social distance from the immediate and the local" (Popkewitz, 2008, p. 29). Mathematics in the school curriculum "relocate[s] the local and the personal in abstract systems of knowledge" (p. 29). Following the notion of the "homeless mind", Popkewitz argues that school mathematics places "individuals in a relation to transcendental categories that seem to have no particular historical location or author to establish a home and re-inscribed with the anonymous qualities of thought" (Popkewitz, 2008, pp. 29–30). In Western societies, the importance given to formalism and abstraction in the school mathematics curriculum can be expressed as a gradient: International guidelines for the first years of schooling in mainstream school mathematics emphasize the importance of linking what is learned at school with social practices of everyday life (Bryant & Nunes, 2016). The development of abstract and formal thinking is gradually introduced at higher levels of education and reinforced in higher education courses.

This is what happened and still happens in the high school agricultural education at *IFRS-Sertão*. In the past and now, the mathematics course was/is marked by an abstract and formal approach. Moreover, the syllabus and the pedagogy are still the same. However, nowadays, different from the abstract and formal school mathematics, the mathematics taught in the technical disciplines includes new technological resources. As explained by one of the interviewees:

> Today the professional no longer does it by hand, everything is computerized there is a computer program to do everything, modern equipment. In 1988 and 1989, in those days, topography was done like this: I walked 7 days to demarcate the boundaries of the properties, making terraces. I had a theodolite to do it, but it was very simple, "brute force" [manual task]. And in the lesson about this subject there was a whole lot of formulas and I solved these calculations by hand. (Interviewee 2)

The excerpt indicates that in Brazil, the process of modernization in the rural area affected agricultural education. Technology has advanced significantly in the last three decades and modified the processes of agricultural production (Buainain et al., 2014; Pizzolatti, 2004). In this context, "management practices" of rural properties are essential for the farmer to be able to compete and remain competitive on the current agricultural market (Pizzolatti, 2004, p. 10). In other words, the "rural businesses need to have entrepreneurial characteristics" to remain "technically and economically viable" (Pizzolatti, 2004, p. 10).

In the past, the pedagogical practices of mathematics education in the technical courses were connected to the initial process of modernization in the rural areas, where new techniques were used at small scale. In contemporary times, these practices are aligned with the discourse

of biotechnology, that is, of techno-scientific discourse (Bocasanta & Knijnik, 2016; Toledo, 2017). Furthermore, this discourse is strongly articulated to a view on the utility of knowledge to an optimized production for the purpose of maximum profit in a competitive market. For the research participants who attended the school in the 1980s:

> The aim was to train a professional to work at home […] the teaching was directed to that! I am going to give you an example of fruticulture: we calculated in the classroom, everything carefully calculated by hand. When we had to trim the orange tree, the peach tree […] and then the teacher taught us how to do it […] we used a lot the 'rule of three' in those courses. We calculated in the notebook, and then we applied the calculations on the field. (Interviewee 2)

In contrast, the participants who recently attended the IFRS express a quite different view on the utility of knowledge and their education:

> Agriculture has changed a lot in the last decades. We tripled productivity; people embraced new technologies and research is a key point for that […]. At that time, in the 1980's, you produced 30 sacks per hectare and it was good if your reached 50 […]. Today the logic is different; I am producing 70, but I am already thinking about producing 90; it is a different logic. Today the world is capitalist. Then, the idea is to earn money! (Interviewee 8)

He connected the desire of being more productive to his education at the IFRS. He provided an example referring to a course on in vitro culture of GMOs. The teacher provided samples of existing research. Experimentation was carried out and data was carefully registered and digitalized in Excel spreadsheets. Then some formulas for growing particular crops were provided by the teachers, based on the production protocols of *Company X*. The analysis of the experimental data was contrasted with the existing research data, and it became possible to determine what factors made a production more profitable. Then, the students went back to the field to set up new, more profitable experiments. Finally:

> We had to evaluate, compare the productivity and so on. And there we had to know mathematics, to transform the data in the tables to formulas to feed Excel, and here, well, there is a lot of mathematics […] mathematics stuff. (Interviewee 8)

In brief, the mathematics taught in the technical courses conducts the students' conduct in such a way that they become subjectified by the idea that in our time, to be prepared to work in the Brazilian rural areas requires applying research reasoning based on biotechnology as well as to apply neoliberal market rules. As to the mathematics course, students were subjectified by the idea that to acquire abstract and formal reasoning was and is still relevant in the school mathematics course. In the past, they argued that this reasoning was relevant to go further in their studies. Currently, the argument is that the formal and abstract reasoning in mathematics is necessary to the production and use of biotechnology, which is a condition for being successful in current competitive markets.

5 Concluding remarks

The change in Brazilian high school agricultural education through the principle of *learning by research* reverberated through the mathematics taught in the mathematics course and in the

technical courses. Although apparently the contents and the pedagogies of mathematics courses continued to be the same as in the 1980s, the analysis of various mathematics education discourses indicates that new and different articulations had taken place. In the 1980s mathematics were seen as important elements in both further education pursuits and in the transition towards using new technologies to improve local production. In the 2000s, mathematics were strongly connected with the acquisition and use of biotechnology, for the purpose of keeping a profitable and competitive agricultural production. Both the technical courses and the mathematics courses steer the students' conduct in the same direction.

We conclude that the curriculum based on the principle of *learning by research* subjectified the students in a particular way: to work in rural areas requires applying research reasoning based on biotechnology as well as practicing neoliberal market rules. We showed that the subjectivation processes produced by the mathematics education discourse contributed to the emergence of the students' desire to become techno-scientificized neoliberal individuals, with the wherewithal to achieve this desire. These were the conditions that allowed the partnership between public agricultural high schools and *Company X* (the most important producer of GMOs in the world).

It could be possible to say that mathematics education is achieving exactly what the State wants, and what citizens need to fulfill current social demands. This research shows that, indeed, students at the *IFRS-Sertão* become equipped to be the new type of technologists and agricultural producers needed in Brazil. But on the other hand, the articulation between mathematics, techno-science and capitalism poses ethical risks and challenges to mathematics education precisely because of this apparent achievement to meet the needs of social demands. We follow Brown's (2015) analysis on the pervasive way in which a neoliberal rationality "disseminates the model of the market to all domains and activities—even where money is not at issue—and configures human beings exhaustively as market actors, always, only, and everywhere as *homo oeconomicus*" (p. 31). As a result, humans are turned into "human capitals" (Brown, 2015, p. 37) or subjects whose value is reduced to being a capital for the State, for firms and even for the self.

The case of Brazilian high school agricultural education evidences how mathematics education makes students human capitals. The partnership between private companies—such as *Company X*—and schools becomes naturalized and desirable. However, this partnership is in itself problematic, since the public sphere of education is directly linked to private interests. This is what contemporary analysts have argued to be an element of the post-political condition (Wilson & Swyngedou, 2014) in which the management of the State privileges private interest rather than the common good. This means that the very same conditions within which mathematics education takes place are changed. And as we have shown, a new configuration has emerged, conditioning what is taken to be mathematics.

Furthermore, the value of mathematics becomes clearly subordinated to an economic rationality within which it functions to maximize market value. This is a point that Pais (2016) has highlighted when examining mathematics education as a matter of economy. This means that a good successful mathematics education in this configuration is mainly an effective tool for the neoliberalization of the individual. While the call for strengthening mathematics education alone or in STEM is broadly celebrated, it seems problematic to adhere to an education that contributes to the fabrication of a *homo oeconomicus*. Our analysis revealed how students enunciated that there is a close relationship between mathematical abstraction and formalism and the production and use of biotechnology. The point is that they learned to think that there is a particular type of techno-science and a particular form of economic rationality that are desirable and beneficial. To be professionally successful, it is

necessary to use GMOs, and to run their business under a logic of competition in the market. Other possibilities—such as organic agriculture or cooperative forms of organization—are not considered an option. Mathematical formalism and abstraction are then set at the service of one particular interest, and mathematics education is surrendered to this interest. Is this what mathematics educators would accept as an ethically defendable and responsible position?

Although our analysis underscores the heavy-handed force of subjectivation processes in mathematics education, we are conscious that there are openings in such context that were not highlighted here. We want to avoid a deterministic perspective, never forgetting that subjectivation processes happen in a space of freedom (Hacking, 2004). Lines of flight may emerge in such spaces (Deleuze, 1995). By pointing to the contingency of the articulation between mathematics education, techno-science and the making of neoliberal subjectivities, we remind the reader that there is always the possibility of imagining and doing what seems not yet considered to be possible (Valero & Knijnik, 2015).

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