FORMAL INCLUSION AND REAL DIVERSITY IN AN ENGINEERING PROGRAM OF A NEW PUBLIC UNIVERSITY

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Political measures are being taken to "democratize" access to universities in Brazil. A new State university recently created after a wide consultation to the population, has taken two important measures: (i) it reserves fifty per cent of its places to poor students and ten per cent to physically handicapped ones and (ii) has abolished the departmental structure. The paper discusses the result of a strategy adopted to deal with the highly heterogeneous classes resulting from the first measure and presents a way of taking advantage of the absence of epistemological control by a mathematics department to offer interdisciplinary objects as possible students' objects of desire.

INTRODUCTION

"I, Diogo Isidoro Gurgel Mascarenhas, declare that, among other possessions, am the legitimate master and owner of a slave of the name of Ana received form the heritage of my father, Lucio Gurgel Mascarenhas and since the said slave is my mother, and since today I come to age, as certified by the marriage of yesterday, therefore, finding myself in the right, I concede to the said my mother full freedom that I concede with all my heart" [Coimbra, 2003].

It seems that only recently Brazilian society has realized the severe exclusion processes, racial as well as economical, that are still going on since much before 1869, date of the above public statement. A feeling for inclusion is now sweeping the country and measures are being taken, such as the "zero-hunger" Presidential program and the "democratization" of access to universities. However, if inclusion becomes necessary it is because diversity has already made ravage. A new public university[1], recently created after a wide consultation to the population, has taken two important measures towards inclusion: (i) it reserves fifty per cent of its places to poor students and ten per cent to physically handicapped ones; (ii) it has abolished the departmental structure. The first measure is directed against entrance discrimination and is justified by the argument that poor students deserve a *compensation* for being confined to public schools, held as offering a lower quality teaching than the expensive private ones. The second measure is directed against the exclusion process inside the university under the argument that the hard-sciences departments crate themselves into narrow epistemological conceptions, develop a

[1] UERGS, State University of Rio Grande do Sul, the southernmost State of Brazil, was created in 2002 as a multi-campi university devoted to boost culture and production throughout the State.

sneering attitude towards other areas and are responsible for the failure of many students driven out of the university.

The paper reports on a research project to deal with the conditions that these measures impose on the mathematics classrooms of an ambitious Engineering Program on Digital Systems in the periphery of a three-million inhabitants urban agglomeration in south Brazil. Students of the traditional federal down town university prejudicially refer to us as “a university for deficients”. We engaged in this Program in August 2002 and were entrusted with the teaching of six one-semester courses on calculus, analytical geometry and differential equations. We immediately established a research project in Mathematics Education that includes our teaching activities and is guided by the question: how can mathematics teaching best supply the demand of this particular engineering program? The degree of generality of our findings hinge on three points that may be common to other universities and programs. 1) The reservation of places obliged us to deal with highly heterogeneous classrooms in an effort to revert social exclusion through mathematics [Gates, Lerman, Zevenbergern, 2003] and having “social justice as a desirable outcome” [Mesa & Sounders, 2003]. 2) The absence of a mathematics department set us free from the control of the mathematical science and obliged us to seek the legitimacy [Chevallard, 1989:63] of our objects of teaching in the consensus of colleagues of subsequent professional courses, specially the physic teacher, seeking to “integrate the teaching of mathematics and sciences” [Keller and Marrongelle, 2003]. 3) Since the University is new, there is no tradition that we can count upon nor that can hinder us. On the contrary, the contribution of the institution to the formation of systems of beliefs [Gates, 2001] leading to the formation os students identity [Brown, 2003] as future engineers is to be established by us, in so far as we develop our activities.

METHODOLOGICAL AND THEORETICAL CONSIDERATIONS

The need to impress change on reality and to build tradition, led us naturally to adopt the methodology of action-research. The colleagues to whom we communicated our research intentions agreed that these were relevant for the Institution and agreed in constituting the research forum of such a collective problem.

The main proponents of action research [Elliot, 1991, Zeichner, 1998] seem not to have been able to avoid action research to be considered as a second-class research method [Cohen and Manion, 1994:189-193]. They do not clearly dismiss the idea that the necessary reflection accompanying any teaching action aiming at enhancing learning, might be taken as genuine action-research. Therefore “some teachers see their practice of planning, teaching and reflecting on teaching as a research process” [Jaworski, 2003]. Although we too carry out such reflections, they are only part of our research problem, which is adjusting mathematics teaching and creating tradition to a new Engineering Program. Accordingly we adopt a wider conception of action-research:

> “Action research is a kind of empirically based social research that is conceived and carried out in close association with an action or solution of a collective problem in

which the researchers and the participants implied in the situation or problem are involved in a participative or cooperative way" [Thiollent, 1998:14].

Furthermore, we contend that there is no research that does not impress some change on reality and therefore *is* action research, *lato sensu*. However, due to a narrow concept of 'action' many researchers ignore or avoid to consider the social effects as part of their research's action. Once attributes have been assigned to different institutionally defined social agents as 'the teachers' and 'the researchers', the unavoidable consequence is a problematic relation between theory and practice and an increasing hierarchy between academy and school. The results are the many not very fruitful efforts "to bridge the traditional gap between theory and practice" [English, 2003], "to bridge the school/university divide" [Jaworski 2003], to solve the "dilemma" through "collaborative research" [Carrillo, 2003].

Once research extends its focus to include its own actions in reality, human subjects including the researchers, are implied and the field of affect is open, together with cognition. J. Falcão suggests that the dichotomy affect/cognition can be avoided if we choose "a more productive unit of analysis (that) targets cultural situations in the context of which a mathematical activity takes place involving a set of identifiable epistemic contents (a conceptual field)" [Falcão et al, 2003:274, Falcão, 2003]. However, if we accept to "look at social forces not only as acting *on* us but also as acting *in* us" [Gates 2001:18] we are led to recognize our own state of dependence as affective human subjects and the hope for an external point of view from which a synthesis of affect and cognition would be possible, vanishes. Thereafter a theory that places at its very center the dialectics of the Subject and the Other, a *mismatch* as constitutive of the Subject, becomes necessary and we are led to the philosophy of Hegel-Lacan as a theoretical framework.

According to Lacan, the theorizer has to accept that no theory will never cover up reality and the research-teacher will have to fully assume his/her part in the interplay of desires in the institution, including the classroom. However, since Adam left Eden, desire is not substantive, it lies only in its effects and presents itself through *objects of desire*, none of which is perfectly satisfactory, so that actions do not generally match declared intentions and the game has to restart. To make the mathematical object into his/her students' object of desire is the dream of all mathematics teachers. We are a little more ambitious, we seek to constitute *institutional professional objects* with mathematics built-in, as students' object of desire. To realize our dream we count on our ability to work out the *pedagogical transference* [Cabral and Baldino 2002] starting from our declared intentions as research-teachers. Our intentions hinge on three conceptual heads: epistemology, didactics and pedagogy.

EPISTEMOLOGY

By *epistemology* we mean the institutional legitimacy of the objects of knowledge brought into the classroom. In accordance with our colleagues we decided to make wide use of infinitesimals, not as a metaphor or an *ad hoc* strategy to find integral formulas, but as a true *object of teaching*. In the exams the students are required to calculate differentials of polynomials and rational functions by the *method of infinitesimals* and to write down the *infinitesimal elements* of area, volume, pressure, moment of inertia, electric field and so on, *before* they put an integral sing in front of them and choose the limits of integration. The number line (the *continuum*) is referred to as being "thick", that is, as holding infinitesimals, monads and infinite numbers, besides real numbers, just as we contend that Cauchy thought of it [Sad, Teixeira, Baldino 2001].

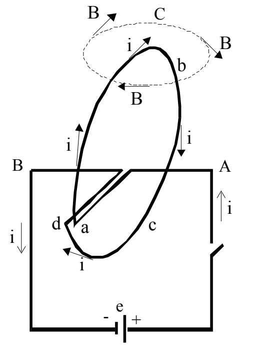
The epistemological difference between infinitesimals and limits about, for instance, the concept of area is striking. According to the Weierstrassian theory of the "meager" real continuum the area is *defined exactly* as a certain real number obtained from Riemann sums. The student is asked either to reformulate his previous concept of area so as to adjust the definition or, at least, never to refer to it as 'area', because, thereafter, this word will have a new 'precise' meaning. Mathematics becomes a formal science. On the other hand, if we adopt the "thick" hyper-real or Cauchy's continuum, it is the concept of area that develops itself, both historically, from the Egyptian scribes to the present, as well as logically, from the simplest Brazilian peasant to calculus textbooks. At a certain point of its development, the concept of area *expresses exactly* the area under a curve as an infinite sum of infinitesimal elements $\int_a^b f(x)\,dx$ and this area is calculated *approximately* (up to an infinitesimal) as $F(b) - F(a)$. Mathematics remains a conceptual science. We clearly aim at establishing the infinitesimal way of thinking as a tradition of the Program.

DIDACTICS

By *didactics* we mean the ordered set of mathematical objects introduced into the classroom as a focus for transference. It was decided to introduce objects from other courses into the mathematics classroom whenever possible. For instance, we introduced the RLC series circuit as a genuine object for our differential equations course, hoping to make it into an institutional professional object, since it is also studied in physics and forms the basis for electrical circuit courses. In the action-research forum it was decided that we should not work the associate second order differential equation in terms of the electric charge in the capacitor, as most mathematics books do, but adopt the integro-differential form, in terms of current, as needed in electricity. We reviewed our undergraduate physics courses so as to be able to call for students' understanding of physical phenomena and to use the proper units and meaning of constants. The following episode is illustrative of such an attempt.

We had set the comparison of the integral and the differential forms of Maxwell's equations as the main objective of our third-semester two-months course on vector calculus. We started the subsequent two-months course on differential equations with the harmonic oscillator as a model for the mass-spring system and the RLC circuit. So it became natural to ask the students to explain the performance of the inductance from the Maxwell's equations. In searching the answer to our question we stumbled into a paradox that kept us puzzled for a couple of weeks. We introduced the paradox to the students, told them that we did not know the answer, suggested that they asked other teachers in ours and in the federal university that they might contact and, promised them a bonus for intelligent suggestions. We received many interesting contributions from experienced colleagues, both in mathematics and in physics, before we could find out our mistake that had also passed unnoticed to them. We contend that the paradox has arisen because of our insistence in integrating physics and mathematics in the same object. Indeed in most physics manuals, Maxwell's equations are presented at the end of the course, after the Laws of Faraday for induction have been discussed, so that explaining inductance from those equations is out of question. The exception is Feynman [1972]. This paradox worked as a genuine institutional object for two weeks. It could only arise because the dichotomy of different departments was surpassed by the university inclusion policy. Here is the paradox; due of lack of space we leave its solution to the reader.

Consider a circuit with a coil and an *emf e* (figure). For the qualitative analysis made here, a one-turn coil is as good as an n-turn one. Turning the switch on, an increasing electrical current starts circulating in the indicated sense. Hence *the potential in A is greater than the potential in B*.



A paradox

The fourth Maxwell equation applied to the curve *C* (upper part of the figure) implies that the circulation of the magnetic field around *C* is proportional to the current *i* across the surface bounded by *C* (the parcel due to the variation of the electric field across this surface being null). Since the current is increasing, the magnetic flux across the surface *abcd* bounded by the coil is also increasing. Considering the curve *abcd* that follows the turn of the coil clockwise, the third Maxwell equation implies that the circulation of the electric field along this curve is *minus* the rate of change of the magnetic flux across the surface *abcd*, being therefore negative. Hence the electric field along this curve must be pointing in the opposite direction with respect to which the circulation is calculated, that is, in the sense *dcba*. But the electric field always points from the higher to the lower potential, hence *the potential in B* (the same as in *d*) *is greater than the potential in A* (the same as in *a*).

PEDAGOGY

By *pedagogy* we mean the set of rules, the work contract that regulates the relation student/object; these rules lead to the constitution of institutional professional objects. The first negotiation of the work contract was very difficult. There was no 'last semester' to which we could refer in order to introduce our classroom rules that included mandatory daily-assessed group-work with teachers' expositions at the end. A considerable group of students (group A) voted for traditional lectures. Within two weeks most of them stayed in the garden, playing cards during the expositions that they had asked for. Recently one of their leaders confessed that she always passed with good grades in elementary and high school but never had to open a book at home. Now when she finally convinced herself that there was no other way to get a passing grade she was facing difficulty in getting concentrated. Some of these students are of the kind that we would call 'bright'. They always have a ready answer to any question, no matter how complex it might be. Most of their answers do not make sense or make only an allusive sense. Typical of their discourse is the following pearl: 'the gradient is the slope of the only tangent line to the tangent plane'.

Other students of group A do not display the same brightness; nevertheless they try to behave as if they did and they join the others in the game of cards. Strange behavior of people who travel seventy kilometers everyday back and forth to come to the university and say that they want to master high technology, we thought. Where is their desire? We soon found out.

Indeed, in the first few days of course we came upon a group of students (let us call it group B) who did not recognize the function x^2 and could neither produce its table nor draw its graph from the table. Here is a true mathematics educational problem, we thought, and we set ourselves to solve it. This group represented one third to one fourth of the students of each of our two forty-students classes. We thought that if we succeed in making this group to show a reasonable progress, all the rest would follow. We committed ourselves to "leave no student behind", we arranged our class schedule so that both could be always present in the classroom and organized extra classes for these students. We put one student at a time at the black-board and asked for contributions from the others as described in [Cabral and Baldino, 2002]. We soon found out that their difficulties were bigger than we thought. These students could not use the rule of three, when asked how much is twelve times 147 divided by 147 they required a calculator, they could not evaluate the simplest arithmetic expressions nor solve the simplest algebraic equations and for them, the largest side of any triangle was always the 'hypotenuse'. One of them could not solve this problem: four chickens weigh five kilos; how much weigh two chickens? After half an hour, under our insistent stimulus, her answer was 2,500 grams. Proficiency in our mother language was of no help either: at least two of them, after several attempts, could not repeat the statement of Pythagorean theorem without reading it, much less make any sense of it. During regular classes we dedicated special attention to these students. Sometimes one of us stayed among them while the other took care of the rest of the class. Nevertheless, they could not get started in the exercises of the day [Stewart, 2001 bended by work-sheets] because they could not make sense of what they read. In fact, each student in group B would require a full time tutor during the whole class. They asked their colleagues for tutoring but soon found out that these were not patient enough to deal with their difficulties.

A few of these students showed some progress during certain classes but in the next day it was as if they had never lived through the previous one. The most dedicated ones had an astonishing ability to produce the answers that we expected, thereby producing an illusion of understanding. We carefully avoided such a trap and led the transference relation strictly toward the mathematical objects. In spite of all efforts group B failed all the exams and along the three subsequent semesters gradually quit the Program.

In spite of our efforts, at the closing of the third semester (Dec. 2003) the 80 students admitted in August 2002 exhibit the following situation in mathematics courses: 5 out of 32 (15%) who were admitted into reserved places are getting passing grades and 27 either quit the course or are failing repeatedly; out of a total of 23 who are showing some success, 27 (78%) were admitted into regular places. The situation of the 40 students admitted in March 2003 point to the same tendency. All the thirteen students composing group B were in reserved places.

The behavior of group A now becomes comprehensible. This university was created around a strong feeling for inclusion and it was estimated by the research forum that rejection of a large number of freshmen would certainly raise disapproval of the upper administration. We are all hired on a two-year temporary basis. Group A certainly realized our constraints and estimated that, as long as the not negligible group B was present and had any chance of passing, as we expected, they would certainly pass too, without further effort than coming to the university just to pick up some indications during classes. The cards game was natural, in spite of their declared intentions of becoming professionals capable of mastering high technology. Only at the closing of the third semester some signs of change are being noticed. Out of the 80 students entering in March 2002, 20 concluded the third semester mathematics course and 16 passed. A Hard-working group of able students was finally formed but through a high social price.

As students of group B abandoned the Program, they expressed strong feelings of revolt and blamed “our method” for their failure. ‘We expected new teaching strategies but what we saw was exercises from a book’, they said. They never declared it explicitly but we suspect that they would hope for the widespread “method” used in high schools: one solved sample exercise followed by several equal ones and one of them chosen for the exam. We understand their distress: like the personage Jim in Spielberg’s Empire of the Sun we had believed that we had the power to restore their mathematical ability and we had unwillingly transmitted them our belief.

A FINAL WORD

Compensatory policies have certainly become necessary in face of the severe social processes of segregation in all areas, not only in Brazil. However, the indiscriminate reservation of places in universities without further consideration about the problems that this decision raises, reduces the whole policy to mere demagogy with perverse social effects.

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