School Mathematics Improvement: Administrators and Teachers as Researchers

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This paper presents the experience that we, university researchers, had as educators of school administrators and mathematics teachers. We faced the problem of designing, applying and evaluating a professional development strategy that immersed them in the dynamics of action research. Our main purpose was to begin a questioning process that could lead these people to improve their instructional practices and to generate the space for allowing them to acquire some tools for attacking and solving their every-day problems. We discuss some of the issues that arose in this immersion and draw conclusions about the meaning that "teachers and administrators as researchers" has for us.

Introduction

Colombia, like many other countries in Latin America, is not satisfied with the way mathematics is taught and learned in schools. The analysis by the Ministry of National Education through its National System for the Assessment of Education Quality (MEN, 1992) shows that there is a serious "deficiency in the quality of mathematics education related to problem solving in daily life. The achievements attained by students in the mastering of usual and new algorithms lose their meaning. Students are able to execute algorithms, but they cannot propose them when solving a concrete problem" (p. 61). For us, dealing with this problem imposes not only the need to produce scientific knowledge about the reality of school mathematics, but also to look for strategies that may contribute to the improvement of the current situation.

Having this challenge in mind, we began the PRIME Project[1] (Empowerment of School Mathematics through a Network of Educational Institutions). In its first two stages[2], this project had as one of its aims designing and applying a professional

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[1] The PRIME Project has been supported by the Corona Foundation, the Ministry of National Education, the Restrepo Barco Foundation, Colciencias, the Inter-American Development Bank, and the Capital District Institute for Research and Teachers Professional Development (IDEP).

[2] The first exploratory stage of the project was called the "MEN-EMA Project". It began in January and finished in December, 1994. During it, ten public schools of the Capital District of Bogotá, two mathematics teachers, the principal and the head of the mathematics department of each school, together with two coordinators from "una empresa docente" (the research centre on mathematics education from the Universidad de los Andes in Bogotá, Colombia) participated. For further details on this project, see Gómez & Perry (1996) and Perry, Gómez &

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development strategy for mathematics teachers and administrators. The core of the project is the assumption that an improvement in the mathematical understanding of students can and should be achieved through the collective effort of these actors, once they become aware of their roles within the school structure in respect to the teaching of mathematics and question their practices in order to improve them.

Even though mathematical knowledge is constructed in the classroom by means of the interaction between the teacher and the students, a change in the way mathematics is taught and learned cannot be achieved by simply informing the teacher about new methodologies or new results in mathematics education. It is necessary to involve teachers in research activities on their teaching that allow them to be aware of the complexity of their profession. Also, teachers' behaviour in the classroom is restricted by a series of institutional factors that shape teachers' performance (Rosenholtz, 1991). Thus it is imperative to involve administrators in other research activities that help to create a space where the institutional policy concerning the teaching and learning of mathematics can be discussed and improved.

In this paper we want to concentrate on the activities that we, as coordinators of the project, developed for immersing both teachers and administrators in a professional development strategy in order to lead them to pursue research activities within their educational institutions. We will address the assumptions underlying the strategy proposed and describe its main features in terms of its principles and activities. We also want to discuss some issues we faced in the implementation of the strategy, related to the tensions that arose when the participants faced the actual realisation of their own small research projects in their schools.

The Professional Development Strategy

Some basic assumptions. The need for change in school mathematics has been addressed in Colombia through several initiatives that focus on one of the actors and/or factors involved in the complexity of it. For example, teachers have been identified as the most important and almost the only group responsible for the students' mathematical understanding. As a means to tackle the problem, several in-service training courses offered nationwide try to transmit to the teacher the latest knowledge about methodologies for the teaching of mathematics, assessment, or even the constructivist theories for the learning of mathematics. The results of this kind of traditional course are far from coping with the requirements of teachers' professional practice (MEN, 1992, p. 89).

We wanted to propose a type of formation strategy that motivates "the construction of a socially aware critical attitude that enable instructors to observe and analyse their own practices with the purpose of improving them, so they can provide a better mathematical schooling for the student; and the construction of a self-multiplying empowerment that moves the instructors to share their experiences, to accept criticism from their peers and to maintain a constant attitude of contribution to the process of strengthening the system" (Gómez & Valero, 1995, p. 7).

Valero (1996). The second stage, called the "PRIME I Project" started in January, 1995 and finished in July, 1997. During this stage, a group of fifteen schools—eleven public and four private from the Capital District of Bogotá—and their corresponding couple of mathematics teachers and administrators, principal and head of the department, was formed and was coordinated by four researchers from "una empresa docente".

Related to these aims, we established two main assumptions that support our actions as teacher and administrator educators.

1. Change is attained through the transformation of individuals. People usually hold certain ideas about themselves and their possibilities of action. Setting out a process of change within an institution demands influence upon such conceptions. Only by dint of personal change in administrators and teachers concerning their managerial and instructional practices can a dynamic restructuring of the institution as a whole be motivated; and such a restructuring is a basic condition for improving quality in the teaching of mathematics.

2. Every educational institution as a whole is significant. The school is the space where the relationships for the teaching and learning of mathematics are built. Within the educational institution, the efforts of both the heads and the teachers conjoin towards the achievement of a series of development goals for their students. Coherence between administrators' institutional plans and teachers' instructional practices leads to the emergence of a particular internal operating dynamic. It is this dynamic that favours the development of good quality mathematics teaching.

These assumptions lead us to view the functioning of the teaching of mathematics within the school as a system, the Institutional System of Mathematical Education (ISME)[3], where some relevant elements interact. In any educational institution, several activities, values, conceptions and types of knowledge converge and affect the students' mathematical formation: on the one hand, the ones held by administrators and, on the other hand, those of teachers, both as members of a group sharing a professional lore[4] about mathematics teaching and learning, and as individuals. Given their positions, administrators hold power not only to carry out actions but also to entrust responsibilities and to strengthen the teachers' performance and decisions in their professional activity. Teachers as members of a professional team, in turn, know the reference framework established within their academic group, which reflects the way the meanings and values of the group's professional lore mesh.

This lore strongly manifests itself in some practices such as the curricular design, the professional development of the group and the teamwork among teachers. Teachers as individuals hold a particular interpretation of this reference framework that is reflected in their teaching. Mathematical knowledge is constructed in the classroom through the interaction between the teacher and the students. How appropriate this interaction is, in terms of the students' understanding, depends on many factors among which teachers' behaviour in the classroom is one of the most important. This behaviour hinges, other things remaining equal, upon the teacher's mathematical and didactic knowledge and on the teacher's beliefs about mathematics, its teaching and learning (Becker & Pence, 1996; Ernest, 1989a, 1989b; Thompson, 1992). Together with individual beliefs and knowledge, teachers' commitment to all the responsibilities entailed by their own job pervades their professional practice.

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[3] This model has been presented in detail in Perry, Valero & Gómez (1996, pp. 19-24).
[4] The professional lore refers to the customs, ways of life, qualities, trends and preparation concerning the teaching of mathematics inasmuch as they are shared by the institution's mathematics faculty (Hyde et al., 1994, pp. 49-50; Rico, 1990, pp. 36-40)

Guiding principles for action. Supported by these assumptions, we also determined some principles dealing with two different dimensions of the strategy: our behaviour as coordinators of a professional development program, and the tasks that were going to be proposed to the participants to develop within their own schools.

Concerning the role that we were going to play as coordinators, we established that we wanted:

- to adopt a questioning position in the light of participants' work because we have neither the truth nor the right answer for their problems;
- to exploit the participants' knowledge arising from their experience as teachers or administrators and we were not looking for a deep knowledge and understanding of the theoretical background related to their research work; and
- to succeed in leading all the participants to the end of the project; therefore, we adopted a constant attitude of motivation for encouraging the participants' work.

Regarding the activities proposed to the participants as part of the professional development strategy, we decided to articulate the series of tasks taking the action research approach as an instrument to generate a process of change. Action research in the context of our project is understood as a methodology for conducting a critical, reflective and systematic inquiry on one's own practice, aiming at understanding it and at implementing an action that modifies it for improvement.

Some of the features of action research, as described by Kemmis & McTaggart (1992), that interested us the most were:

- the object of study for an action research project emanates from the real and felt necessities of the researcher; therefore, teachers and administrators choose their research problems according to what their milieu demands;
- action research permits teachers to carry out small-scale studies whose goals can be concretely and easily achieved;
- the interaction among the participants—in this case, the exchanges inside and between the couples of teachers and administrators—is a source for collaboration and amelioration of their research activities, that has to be constantly used; and
- the adoption of this style of work favours the birth and consolidation of a critical community that comments, judges and validates their research proposals and activities.

These two kinds of principles led to the series of activities making part of the professional development strategy that is described below.

A brief description of the strategy. The schools involved were selected as the result of a process that began with a general call for participation. This call was sent to about one hundred schools from the Capital District of Bogotá. After having attended a meeting where we explained the purpose, plan of action and conditions for participation, some principals expressed their interest in the work and had an interview with the coordinators. In this interview, we inquired about the principal's actual motivation to generate a commitment from the school with the project. Taking this into account and considering the availability of teachers, we chose the schools that were going to share the experience. Each principal, in agreement with the whole mathematics department, decided how the school was going to be organised for fulfilling the requirements of the project and who were going to attend it directly.

Two research teams were formed, one with administrators and one with mathematics teachers. The first team included the principal and the head of the mathematics department from each school. The second team included two mathematics teachers from

each school. Both teams also included the general coordinators of the experience. Administrators as well as teachers went through a process that had as its pivot the carrying out of an action research project within their schools, as well as a series of seminars and advisory meetings, and writing of a short paper reporting the experience.

Action research projects. Administrators had to identify a particular aspect of the issues related to mathematics in their own schools, which they had the power and the will to modify. Concerning this aspect, they planned a specific action aimed at a change. Then they implemented it, observed its results and evaluated its effects upon the aspect under consideration. Some of these small-action research projects carried out by administrators concerned topics such as:

- the mathematics department meeting as a space for professional development;
- the dialogue and communication among the mathematics teachers as a way of promoting cooperation and coordination of the group;
- problem solving as a teaching methodology for the whole department; and
- the organization of the mathematics faculty for increasing professional interaction among teachers.

Teachers had to choose a topic from the syllabi of their courses at that time, the teaching of which they wanted to improve. They had to complete a curricular design for a maximum of three class sessions, put it into practice, observe its implementation, and evaluate it. Teachers' projects focused on subjects such as:

- the teaching of fractions;
- the teaching of some basic geometry concepts;
- the representation of algebraic expressions;
- the posing of problems implying simultaneous linear equations;
- the solving of problems involving trigonometric functions; and
- the teaching of trigonometric concepts by means of a computer-based lesson.

Seminars

The main purpose of the series of seminars was to support the participants' research process by means of discussing the different stages they were experiencing. In both teams, participants were provided with few conceptual reflections for supporting their research, some aspects related to the action research methodology, and a broad notion of curriculum. The activities in the seminars included individual work, small group work and plenary discussions and presentations. Administrators met in eight seminars, each one four hours long, scattered throughout nine months. They discussed aspects of the social organization of schools. For their turn, teachers attended three sets of sessions, each twenty hours long, distributed over nine months. These were arranged during their schools' working day, so schools had to reschedule temporarily to allow for their absence. Teachers were introduced to some mathematics curriculum models and to some aspects of the teaching of algebra. In general, the seminars opened a space that allowed participants to share their ideas, debate, provide and receive assistance from peers.

Advisory meetings

Furthermore, heads and teachers from each school attended several individual advisory meetings with the coordinators from "una empresa docente". In those sessions, they also had the opportunity to discuss their personal achievements and difficulties, assess the evolution of their projects and set guidelines for the short–term activities following. Thus, a climate favorable to reflect, face up to the issues, assume one's responsibility in them and realise the possibilities to solve them was created.

Writing of papers

After concluding the research activities, participants worked together with one of the coordinators in the preparation of a short paper for publication. This process completed their reflection about their research experience and re-organised *a posteriori* their vision of what their projects were.

Issues Arising from the Strategy Implementation

As seen above, the meaning that we gave to the expression "administrators and teachers as researchers" deals closely with our proposal for immersing these people in the dynamics of a special kind of professional practice. This form of action highlights the relevance of systematic inquiry for performing supported by decisions made on the base of previous reflections, follow-up and further evaluation. For the participants, getting involved in the strategy and committing to it demanded a great effort. We think that this situation may have been caused by the fact that:

- teachers and administrators, in many cases, usually acted and made decisions as an immediate response to current needs but not as the result of an analysis of their situation—this way of acting clearly diverges from the one we wanted them to experience and exhibit;
- these people held preconceptions, even sometimes misconceptions, about what doing "research" is; and
- the strategy was a novel and questioning experience for them.

As a result of all of these complexities, several tensions around research arose. We would like to discuss at least two of those tensions which for us illustrate key points about leading administrators and teachers to adopt research into their practices.

Different visions about research. A first one is the tension between the view that they held in respect to what research is and the view that we wanted to present to them. For most of them, research was an activity which only very highly skilled scientists can make. It also demands that the scientist be trained in the empirical–analytic paradigm and be able to design and apply a series of quantitative methods for gathering data and analysing it. Contrary to this view, we introduced them to the critical paradigm and, particularly, to the action research approach.

This tension had several manifestations in the participants' behaviours and attitudes along the project. One of these was their feeling that they were not able to cope with the project because doing research is very difficult. One administrator claimed that "it was complicated for us to face our research because we are the sons of a behaviourist education". In some cases, there was a trend towards thinking that it is enough to carry out a test and drawing a pie chart that illustrates the percentages of answers found. This was the case of several teachers who evaluated the effect of their curriculum designs by simply saying how many students gave the right and how many the wrong answers to their questions. However, many other people believed that what was proposed was a silly exercise and that it was not worthy to spend extra time on or dedicate lots of effort to it. This was the case for some teachers who abandoned the project during the first week of seminars. One of them argued that "I thought this was going to be different... I expected you to say that we were going to follow one path and study what a given school says about a specific topic... I wanted to read, study and I got deceived because I saw that I was going to do the same things I have been doing... but now, I have realised that your proposal is also valid".

Expectations versus results. A second tension that deserves to be exposed is that emerging from what teachers and administrators actually did as a result of their visions, perceptions, beliefs and experiences and what we wanted them to do in terms of the quality of their process of reflection. Once the teachers and administrators decided to get engaged in the strategy, they tried to give their best. Most of them invested lots of time not only thinking about the questions we posed to them, but also doing what they saw as necessary. In spite of the fact that we tried to empower them and give them freedom to carry out their projects, the conditions and restrictions we imposed made us adopt an unconscious position of pulling participants towards our view of how things are and should be done.

An illuminating example of this tension is the decision we made after seeing the results of the teachers' projects in MEN-EMA. In this first exploratory stage, we stated the task for the teachers in a general way that emphasised the purpose of designing, applying and evaluating a curriculum for a topic whose teaching they found problematic. The results seen in the teachers' reports and papers showed that there were several deficiencies related to the appropriateness of the teaching sequence designed for attacking the problem, to the mathematical content of the activities proposed, and to the depth and systematisation of their reflection as "researchers". Although they felt proud of their work and they were very motivated to continue doing "something different" in their classes—we considered that reaching this state was a success in the beginning of a change process—we also found that they finally built a partial and superficial conception about action research and its connection to teaching practice.

As a consequence of this, we not only modified the presentation of the task for the teachers in PRIME I, but also designed a sequence of activities that leads teachers to the kind of problem definition that we wanted. This time we guided them to posing the problem in terms of a particular difficulty that students usually have in the learning of a mathematical concept. In order to find that difficulty, they had to survey the content of the course they were currently teaching, choose a problematic topic for the students, identify the common errors that the students make in that topic, hypothesise about the reasons (associated to the concept itself) why students make those errors, and choose one of those reasons having as a criterion the relevance teachers give to it in the students' understanding of the concept. The results teachers reached, as observed in their reports and papers, showed that they gained an awareness of the complexity involved in the didactics of mathematics because they were able to analyse in some detail the teacher, the students and mathematics interaction in the classroom. At the end of the experience, some teachers said that "This project made me aware that, although I think my students understand what I say, their real understanding is not as evident as that", and "I understood the complexity of developing a mathematical topic in my classroom and of the students' learning".

However, the process of engaging teachers in the activities we were leading had several obstacles. These included the teachers' limited understanding about the utility of the activities they were "forced" to pursue, the lack of motivation in face of our constant comments on their work, and their feeling that they had no freedom to develop their "own" interests. For example, some teachers expressed the opinion that "The first days were frustrating; we hardly understood what you were asking us to do; therefore, we did not know where to go", and "I tried to do my best despite not having clear what I had to do, but you always told me that things were wrong and I had to repeat them again and again". If these two experiences are compared in terms of the teachers' project quality, the second surpassed the first. But if they are compared in terms of how comfortable the

experience was for the participants and how many of them reached the end[5], the second was a failure.

Dealing with tensions. We tried to resolve these tensions by explaining and clarifying the assumptions underlying the strategy and justifying the reasons for our decisions. We also addressed these problems by reinforcing our personal and direct interaction with them. During the advisory sessions, we dedicated much time to questioning participants and to looking for examples that permitted them to realise the strengths and deficiencies of their curriculum designs. One tool that was quite useful for encouraging a deeper reflection on their research process was the role we played as students. For example, when discussing the class sequence they prepared for their students, we behaved as a low-skilled student would and said aloud what we were thinking. Seeing a "student" reaction generated a profound questioning on how appropriate their proposal was and promoted new ideas for ameliorating their design.

One important factor in resolving the situation was time. As administrators and especially as teachers advanced in their projects, they began to understand why the systematic inquiry into a very small problem offered them the possibility of acquiring useful tools for their everyday practices.

Conclusion

Many factors affected the motivation of these teachers and administrators for applying themselves to their research activities. Having being rather successful in the first phase, we thought that we had "designed" a professional development strategy that, with some improvements, could be "standardised" and used by other university researchers for teacher and administrator professional development. Our plan for the second phase was to make these improvements and have a final design that could be offered to other researchers in Colombia. We have now realised that this is not possible, at least in the short term. Trying to affect the dynamics of the system that deals with the teaching and learning of mathematics within the school is not an easy task at all.

Furthermore, it is not a task for which a ready-made recipe for action can be proposed. As it happens with the teaching of mathematics itself, the problem is extremely complex and depends on many factors. To start with, there is a big difference between informing teachers about some theories or teaching methodologies and trying to affect their behaviour in the classroom through leading them to reflect about their own practice. In order to motivate teachers and administrators to begin this reflection process, and in order for this reflection process to generate some kind of questioning from the participants, it is necessary that the coordinators know and understand deeply the mathematics school system, and the problems, interests and expectations of those who make the system work. It is not obvious to have this kind of knowledge, especially because schools, administrators and teachers have their own particular problems, interests and expectations. This is why we do not think that a standardised professional development strategy can be proposed.

On the contrary, we see the problem of administrator and teacher development through action research as the problem of the development of the coordinators themselves. It is now obvious for us that the coordinators of these kinds of projects need

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5   In MEN-EMA, 80% of the teachers finished their action research projects and attended all the seminars. In PRIME I, 50% of the teachers reached the end of the project, 33% abandoned it in the middle and 17% quit at the very beginning of it.

to be conscious that they have (sometimes implicitly) a vision of what teacher training is, of the factors that affect the behaviour of the teacher and the administrator in their own practices, and of how a teacher training program can be designed and implemented. These visions from the coordinators determine their behaviour and their decisions for action in their day to day interaction with the participants in the professional development strategy. And it is these particular decisions and this particular behaviour that can make a difference between success or failure in this kind of project.

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