Teacher beliefs and practices formed during an innovation with computer-based exploratory mathematics in the classroom

Chronis Kynigos* & Michael Argyris
University of Athens, School of Philosophy, Greece

This paper describes research into the beliefs and practices established over time by teachers, who had been engaged in an innovative ‘mathematical investigations’ school program, based on the use of exploratory software. The theoretical framework perceives the teacher as an active mediator of innovation, constructing and reorganizing a personal pedagogy. Interview and detailed observational classroom data were collected and analyzed, synthesizing qualitative and quantitative interpretations of teachers’ comments in the classroom. The results show that teachers refer to a variety of aspects of the learning situations in which they intervene rather than just the mathematical concepts and ideas. They adopt multiple roles in the classroom and are influenced by the values of the educational system. The ways in which these issues influence teaching and learning of the mathematical concepts at hand is considered. The nature of teacher beliefs and the ways in which they may influence their practice is questioned.

Introduction

In the European educational setting, there is intense and widespread rhetoric in favor of implementing innovations based on computational and communication technology. At the same time, there is a growing concern that, when put to the test, the ways in which this technology is used frequently corrode the designed innovation into educationally trivial activity (Hoyles, 1993). This paper addresses the question of what kinds of issues influence the implementation and establishment of technology-based innovative programs in the classroom, taking the point of view of the teacher (i.e. looking at teacher strategies, beliefs and interactions as the new classroom social milieu is established).

Research studying teachers engaged in innovative programs based on the use of technological tools has so far mainly focused on teacher strategies and beliefs through a perspective in which the subject domain or the technology itself, as designed by the innovator or the researcher, is of primary importance in teachers’ and students’ classroom interactions. We suggest, however, that teachers and students, have their own perspectives of what matters, or what changes when

*Corresponding author: University of Athens, School of Philosophy, Department of Education, Athens, Greece. Email: kynigos@cti.gr

ISSN 1234-5678 (print)/ISSN 1470-1278 (online)/04/030000-00
© 2004 Taylor & Francis Ltd
DOI: 10.1080/1354060042000204414
engaged in something new in the framework of everyday classroom life. For example, teaching strategies might be influenced by aspects of learning situations besides those related directly to the subject ideas and concepts at hand; new types of social roles may be assumed or constructed by the teachers and new roles afforded to the students and the technology. In this study, we took a more ecological approach, collaborating with a group of teachers as they were acting in the classroom during an innovative program, in order to study not only their espoused beliefs, but also the classroom milieu, the interactions with the computational technology artifacts used in the course and the students’ learning process, within a particular framework that is described in the following section.

The project involved a group of primary school teachers who had been engaged in an innovative ‘mathematical investigations’ school program for a considerable amount of time (eight years) before the study took place, and had inevitably had time to shape the course according to their own agendas and pragmatics. Special attention was thus given by us to the teachers’ comments in the classroom, the aspect of the teaching situation that they addressed, what type of student activity they aim to encourage, and what role they constructed for teacher, student and technology.

**Theoretical framework**

Even though it seems self-evident that teachers have always been a prominent factor in educational practice and although the use of technological artifacts is becoming more and more widespread in the classroom, educational research has not always recognized the significance either of these bear on the learning process.

Research on learning mathematics, for instance, has only gradually widened its scope from theoretical perspectives that were focused exclusively on the student and on mathematics, to those that encompassed this relation within social settings, emphasizing the teacher’s role (Hoyles, 1992). Teacher–student interaction, for example, given attention by some researchers in the 1990s, was perceived in relation to the specific setting within which it took place (Thompson, 1992; Moreira & Noss, 1995; Cobb et al., 1997; Raymond, 1997).

This was the result of a paradigm shift in the study of teaching practice, which was manifested through the acceptance of the idea that children construct their knowledge and understanding of the world not just through direct personal experience and discovery (constructivist paradigm), but also through the intellectual sharing and support of those around them (socioconstructivist paradigm). In these terms, the role of teacher is a particular, skilled form of such support (Mercer, 1993). This gave impetus to classroom research with particular emphasis on the interplay between mathematical learning and social interaction (Cobb et al., 1997). The study of mathematical teaching and learning in classroom situations has been one of the important means to develop theoretical interpretations of learning as a reorganization and construction of concepts in social settings (Mercer, 1993; Lerman, 2000). It has also, however, been a means to study teacher beliefs, strategies and interactions in the classroom (Hoyles, 1992; Kynigos, 1996). In the attempt to integrate
psychological and social perspectives, such studies involved perceiving the teacher in terms of her/his role in organizing the class, setting up tasks for the students to be engaged in and supporting their learning process. The notion of the teacher influencing the construction of classroom norms (taken as shared meanings and understandings of actions and roles) was crucial to this perception of the teacher (Cobb & Yackel, 1996) and contrasted previous paradigms focusing exclusively on teacher–student interactions or even ignoring the teacher as an active personality, focusing on ‘teacher performance’ by means of student performance.

This framework for perceiving the teacher thus involved a reorientation of the ways in which the nature of the teaching profession was addressed. It pointed to the conception of teaching as a thoughtful profession, rather than a technical mediation of a prescribed curriculum and to teachers as professionals who have an active role to play in planning curriculum, designing and supporting educational activities (Jaworski, 1994, 1998). Such a stance is based on two assumptions (Fang, 1996). First, teachers are professionals who make reasonable judgments and decisions within a complex and uncertain community, school and classroom environment. Second, teachers’ thoughts, judgments and decisions influence their classroom behavior.

In line with this notion, teacher research has made significant strides, studying the complex relationships between beliefs and classroom practice (Grand \textit{et al.}, 1998; Aguirre & Speer, 2000). Interrelations between teacher pedagogy and teachers’ attitudes towards their role, mathematics and the teaching of mathematics have come into play. Some research efforts have described consistencies between beliefs and classroom actions, whereas others have identified inconsistencies (Thompson, 1992). Distinctions like the one between beliefs and beliefs-in-practice, termed ‘situated beliefs’ by Hoyles (1992), have emerged providing useful insights. The perception of teachers making sense of their environment as they act upon it, constructing and reorganizing a personal pedagogy through interrelation with classroom and school culture, has come into focus (Lerman, 2000).

Besides these perceptions of ‘the teacher in the classroom’, however, little attention has been given to the systemic level; that is, the ways in which aspects of the educational system and the educational paradigm as a whole may influence the types of things teachers take for granted. In central European countries, for instance, and particularly in Greece, there is a strong element of revelation (of knowledge, or of the truth) engrained in the curriculum (Kontogiannopoulou-Polidorides, 1996), part of the cultural heritage of the past century. It may be the case that this would make it much more difficult for a teacher working in this system (rather than within an Anglo-Saxon one) to understand, adopt and value innovation where students are encouraged to generate their own meanings through personal expression, experiment and constructions.

Apart from the bearing teachers may have on student learning processes, the uses and roles of technological artifacts in the learning setting have also been influenced by the paradigm shift from constructivism to socioconstructivism. The initial notion was that learning will be realized simply by giving children opportunities to interact with rich computational environments, to work with open-ended exploratory soft-
ware (Papert, 1980). Research evidence (Kafai & Resnick, 1996) indicated that the computer has the potential to overturn many of the assumptions about what children can and cannot do, the hierarchies of understanding that have been drawn up so far, and the ‘readiness’ of pupils to understand this or that mathematical concept (diSessa et al., 1995). However, such research evidence also indicated that, simply by interacting in an environment, children are unlikely to come to appreciate the mathematics lying behind its pedagogical intent (Noss & Hoyles, 1996). In the light of such findings, the teacher’s role has been recognized in settings based on exploratory software, the teacher became ‘a legitimate field of study’ (Hoyles, 1992) and the pedagogical component identified as a crucial aspect in the design and use of any computational environment (Noss & Hoyles, 1996).

We began by suggesting that both the educational potential and the magnitude of investment needed for the integration of computational and communication technology in school practices have given rise to associations between using technology and the design and implementation of innovative classroom practice. The process of innovation and the factors needed to be taken into account for its success, however, have proved problematic and have gathered research interest. Noss and Hoyles (1996), for instance, argue that the implementation of any innovation, which fails to take account of the teacher and the teachers’ work situation as mediators of the innovation, is doomed to fail. The ways in which we may take the teacher into account, however, are far from obvious. Olson (1992) provides an illuminating classification of approaches respecting the implementation of an innovation: the bureaucratic and the reflective approach. The former leads us to perceive teachers as professionals who should be trained to transmit the objectives of the innovation, that is to form a package of curriculum innovation first and then to graft teachers into it. This is a notion, which in the long run denies the creative element in the teacher’s role (Budin, 1991). The latter, considering the ways teachers make sense of their environment as they act upon it, conceives them as subjects who may bring about change as they reflect on their own practices (Artzt & Armour-Thomas, 1999). It advocates that it is for teachers to work to clarify a set of ideas and practices, which will emerge gradually in the course of the innovation (Olson, 1992).

In this section, we thus argued that the issues of the ways in which teaching affects learning, of the teacher as a professional and of the implementation of innovations through the use of technological artifacts, have given ground for much debate and alternative ways of perceiving what goes on in the classroom. We thus felt it was important for this study to articulate a framework with which we approached the teacher as he/she was engaged in technology-based innovation in the classroom. We thus perceived the teacher as a professional who constructs and reorganizes a personal pedagogy through interrelation with classroom culture and the wider culture, acting as a mediator of an innovation rather than as one who implements pre-prescribed teaching methods or innovations (Olson, 1992; Moreira & Noss, 1993; Prawat, 1996). Our approach has been to study the teaching process in the context of using a special kind of technological artifacts called ‘exploratory software’ (diSessa et al., 1995) to mediate innovation, taking into account that computational environments inevitably perturb the dynamics of the classroom, make more
apparent the mathematical beliefs and understandings of teachers and students and provide a window, a magnifying glass even, on the interaction process (Hoyles, 1992; Laborde, 2001).

In this paper, we report on research into teachers’ beliefs and practices constructed after eight years of innovative practice involving a one-hour-per-week computer-based mathematics classroom activity with small cooperating groups of pupils. The research was conducted in two different time periods in the same school, involving 12 teachers.

Research setting

The study took place in the context of a longitudinal primary school initiative to establish a weekly hour where each class with their day-to-day teacher engaged in small-group collaborative project-work based on new technologies (Kynigos, 1996) (Latseio Psychico College, Athens). Apart from work in small groups, what was innovative for the school was for the students to engage in exploratory activity involving the progressive construction of models using exploratory and expressive software (Logo programming language, word processor, paint program) and for the teachers to didactically support this kind of learning. At the end of each ‘investigation’, which typically lasted for 10 weeks, the students composed a written presentation of their work (including the problems they encountered, ways in which they solved them and how they worked together in their groups) and presented it to the rest of the class. The theme of each investigation was negotiated between the teachers, the school head and the researchers who acted as consultants to the school initiative and as inservice teacher educators.

Teacher education in educational uses of exploratory and expressive software, carried out by the researchers, was built within the teachers’ working schedule. It was systematic but non-intense or directive. The researchers’ main agenda was to set up opportunities for the teachers to reflect on their practice and to encourage them to develop their own personal pedagogies. The researchers did not offer specific direction concerning the teaching method. The teachers were thus left to use the technology to set up an unconventional classroom practice and develop strategies for a pedagogy encouraging collaborative investigations. However, the main points of supporting collaboration, personal engagement, constructions and investigational work were agreed upon by the direction, the researchers and the teachers as a framework for this initiative, which was perceived as innovative with respect to traditional everyday practice.

At this point it should be noted that the Greek educational paradigm is characterized by an emphasis on content, abstract knowledge, teacher-centered approaches, a lack of systematic pragmatic orientation (Kontogiannopoulos-Polidorides, 1996) and it is rather centralized as the content and, to some extent, the process of education is formulated by the Ministry of Education. It was thus in this context that the ‘investigations’ hour took place.
Method

In the aforementioned setting we set out to investigate the teachers’ beliefs-in-practice. Our focus was on the teaching practices constructed with computer-based exploratory mathematics. The fieldwork was carried out in two distinct phases, our research objectives in the second phase emerging from the analysis carried out on the data from the first.

During the first phase, the students were engaged in investigating ways to construct circles with the Logo language in order to create designs including circular shapes of different sizes. Our research focus was on

(a) the teachers beliefs regarding the learning of mathematics, their pedagogical role and the role of the computer; and
(b) their intervention strategies regarding the aspects of the learning situations they referred to, the extent to which they were embedded in the pupils investigations and the kind of activity they intended to encourage.

Eight teachers were observed during three teaching hours each.

During the second phase, about one year later, we had the opportunity to return to the same school and observe the teachers again after having analyzed the data from the first phase. We felt that in order to obtain a clearer insight into the teachers’ beliefs in practice, we needed to extend our research beyond the identification of the issues described in (b) and to gain better understanding of the reasons behind the teachers’ intervention strategies and the ways in which the classroom social and temporal context influenced these. We therefore needed to study the social interaction process further. The focal point in the second phase was thus to investigate:

(c) the nature of the roles undertaken by teachers in the learning situations in which they intervened, the mode of communication they adopted in these; and
(d) the influence of aspects of the classroom context and the wider educational context.

For this purpose, five of these teachers were observed for six or seven class periods, respectively, during a two-month project, the object of which was for each group of pupils to find out quantitative geographical information on Europe and represent it in a series of bar charts.

Both phases of the study involved teacher interviews and studied teachers’ practices within the classroom, understanding them as members of this specific environment. Exploring their practices, we tried to trace their beliefs-in-practice as constructed in the specific setting and contrast them with their espoused beliefs as stated in their interviews. In both phases teachers were videotaped. A microphone enabled transcription of all their utterances, capturing responses of the group of pupils in which they intervened. Semi-structured interviews were subsequently carried out regarding research questions at hand. Background data was also collected (i.e. students’ written presentations of their work, field notes). Verbatim transcriptions of all audio recordings and interviews were made.
In the first phase we developed an instrument for recording classroom events building on previous work by Hoyles and Sutherland (1990) and Farrell (1996). Our focus was on which aspect of the learning situation the teacher referred to when they intervened in student work and on what kind of student activity their intervention intended to encourage. In the second phase we had one video camera focusing on the teacher exclusively, while a second video camera was focusing on various groups of students, capturing the climate of the classroom. The teacher was equipped with a remote microphone. We analyzed the data by modifying the instrument for recording classroom events used in the first phase. In order to obtain a feeling for the balance of teacher actions in time (temporal contextual issues), we separated every teaching period in one-minute time segments and we studied the appearance frequency of each role and activity for every teaching period.

In both phases we used the work of Hoyles and Sutherland (1990) and of Farrell (1996) as a framework, but adapted our observation instruments to address categories of teacher comments as they emerged from the data, instead of using data to test preexisting hypotheses. At first we read through the data focusing on comments made by the teachers that we thought would inform us about their strategies and intentions. We then looked at the notes, grouping them so that a sensible structure would emerge. Then we reread the data assigning teachers’ comments to these categories and negotiating on the rationale for doing so until, as researchers, we achieved a common understanding. These categories appear in the subsequent ‘results’ sections. After that, we counted the data carrying out some quantitative analysis described in the subsequent sections. We also carried out qualitative analysis, identifying a number of real-time episodes, which would allow us to illuminate the issues further. In the ‘results’ sections, we thus use a combination of quantitative data on teachers’ comments, characteristic classroom episodes and a detailed analysis of a longer episode, which we call a ‘vignette’, in order to highlight some of the issues not evident from the quantitative data analysis. Finally, we came back to the original text using the quantitative picture supportively in order to describe the practices of the teachers involved.

The activities

In the first phase, the students’ (nine year olds) activity was to experiment with constructing circles and curves in Logo and then to create a design of their choice containing different circles, using what they had found out during their circle investigation. Constructing circles with the Logo language involves giving commands to the Logo ‘turtle’ to make repeated moves and turns. This creates a polygon-like figure, which approximates a curve (definition of circle as polygon-approximation) when the values of moves (distances) and turns (degrees) are small (e.g. less than five). The ‘curve’ turns into a full circle when the number of repetitions times the value of each turn is 360. Students were encouraged to think that they themselves are walking on the trace of the curve impersonating the turtle. (Papert [1980&rupsb; called this type of activity body, syntonic.)

In the second phase, the students (11 year olds) carried out a geography project, where they had to find numerical data of European countries and construct bar
charts to represent them on the screen. Research has shown that with paper and pencil ‘technology’, students and teachers seem to focus much more on the design and precision issues of constructing graphical representations rather than on the mathematical ideas involved in what and how they represent data (for a discussion, see Ainley et al., 2000). The geography project was suggested by the teachers during a teacher education seminar. It was encouraged by the researchers who were aiming to build some mathematical programming activity into constructing a dynamic bar chart. Teacher and researchers agreed that the result of constructing the bar chart in this way would subsequently allow more focus on the representational issues. The mathematics on the teachers agenda was thus not only to represent data by means of a bar chart, but also to focus on the process of constructing the different bars (rectangles) in a sequence and finding ways in which the whole construction would not have to be repeated for each chart. Thus children would have to make a program to construct rectangles, with one variable for their ‘height’, adopting, in a sense, the role of software developers (for a related discussion, see Kafai & Resnick, 1996). They used a piece of software called ‘Turtleworld’ (Kynigos et al., 1997) (see http://e-slate.cti.gr). ‘Turtleworld’ is similar to the Logo language, but has a special feature allowing dynamic manipulation of the result of parametric programs constructed in Logo (called the ‘Variation Tool’). The tool provides a slider for each variable (parameter). Dragging a slider has the effect of the figure dynamically changing as the value of the variable changes sequentially. The effect is a combination of Logo-like symbolic expression software and dynamic manipulation software for geometry. The teacher wanted the students to suggest that they construct a rectangle procedure with one variable for its ‘height’ and then use the variation tool to create a ‘bar chart machine’ (i.e. a piece of software for creating bar charts) (Kynigos, 2002).

Identifying types of teacher intervention

Phase 1: Notional units of analysis

Comment characterizations. We analyzed the teachers’ discourse into ‘notional units’, giving each a characterization according to our interpretation of: (a) whether it was embedded in pupil activity, (b) to which aspect of the learning situation it referred, and (c) the kind of pupil activity it intended to encourage (see Kynigos, 1996; for the latter, see also Hoyles & Sutherland, 1990). We identified these ‘discourse units’ by negotiating between ourselves to relate each one to the characterizations themselves using pilot analyses of the same data to check for interpretative discrepancies. Table 1 provides a representation of this analysis, showing how each embedded comment was further given three characterizations according to the aspect of the learning situation to which it referred, the teachers’ intent and the type of reflective or directive comment. The aspects of the learning situations, which the researchers perceived as distinct when analyzing the data, were those that referred to the subject domain (maths and Logo-maths), those that referred to technical issues and those that referred to the learning process (process, group dynamics). With respect to the
Table 1. Aggregate relative frequencies of comment characterizations (%)

<table>
<thead>
<tr>
<th>Embedded comments</th>
<th>Intent</th>
<th>Math and Logo math</th>
</tr>
</thead>
<tbody>
<tr>
<td>mathematics</td>
<td>5</td>
<td>reflective past</td>
</tr>
<tr>
<td>Logo mathematics</td>
<td>31</td>
<td>reflective future</td>
</tr>
<tr>
<td>computer</td>
<td>19</td>
<td>motivational</td>
</tr>
<tr>
<td>process</td>
<td>25</td>
<td>directive discipline</td>
</tr>
<tr>
<td>group dynamics</td>
<td>10</td>
<td>directive method</td>
</tr>
</tbody>
</table>

The information in Table 1 indicates that:

(a) the embedded comments (90%) by far outweigh the disembedded ones;
(b) there are few motivational comments, implying that there was little need for teacher-prompted motivation;
(c) we do not have a significant difference between reflective and directive comments on the whole, but have significantly more of the former when it comes to comments with specific reference to mathematics and Logo-mathematics; and
(d) regarding the reflective comments in the latter two categories, we have significantly more of those referring to the past.

In general, we see a large percentage of comments with no reference to mathematics (at least 54%), which at least supports justifying the characterization with respect to the aspect of the learning situation and provides some indication of the nature of the discourse and classroom culture.

In order to investigate deviations from the aggregate picture of individual teachers’ comments and of specific comment categories, we calculated the ‘expected’ values (the values corresponding to the aggregate score), did a chi-square test for the differences between observed and expected values and then tested for the significance of each difference individually using a special test taken from biometrics (Haberman, 1973). We then observed the significance of this difference in two ways: ‘horizontally’, in order to study variations among comment categories; and ‘vertically’, to do the same with variations among teachers. The results show that we have large variations regarding the aspects of the learning situations and insignificant variations regarding intent. For example, in the former comment category, only 1/8 teachers were close to the expected values for the procedure and group dynamics categories, and 4/8 and 3/8 for the mathematics and Logo-mathematics categories respectively. Moreover, regarding these four categories, only two teachers were close to the expected values in three of them, and three teachers varied significantly in all four. The rest were close only with respect to one aspect. With respect to intent the
picture changes, as presented in Table 2. On the left-hand side we have the ratios of teachers with insignificant differences to the expected values. In the center and on the right-hand side we have the ratio of intent categories for which each teacher did not vary significantly from the expected values.

Furthermore, as pupil grade increases, the results show a decrease in mathematics, group dynamics and process, while there is no such trend regarding Logo-mathematics. Regarding mathematics, this could indicate that the teachers relate less and less school mathematics to exploratory mathematical activity as the pupils’ age and the school mathematics content changes. This may point to the need for further reflection on the part of the teachers on how to help the pupils synthesize understandings emerging from this activity to school content (Hoyles & Noss, 1993).

Two types of information were thus derived from the combined analysis of reference to aspects of the learning situation (as these aspects emerged from the data) and intended encouragement of types of pupil activity. We suggest that this is helpful in describing teaching strategies as they are constructed during teaching practice. The aim was to gain insight into the ways in which the classroom culture and the dynamics of the situations emerging within each group of pupils interacted with teacher beliefs and teaching strategies regarding the aforementioned and mathematical ideas. Although these results are useful, there are limitations in their interpretative power. A major problem is the extent to which each comment can be connected to the context of the situation it was made in. It is not easy for instance to draw information on whether a comment referring to one aspect of the learning situation has influence on another aspect. The same applies for the types of activity. For example, taken out of context, the interpreter may characterize the following comment as referring to Logo-mathematics, since the discussion seems to be about a turtle turn. Following all the interventions regarding these two pupils, however, revealed that the teacher was really trying to establish communication between them—so the comment refers to group dynamics.

Wait a minute, wait a minute. Andoni, whenever you think of something do you just do it or do you communicate with the others? Because just now Nikiforos was puzzled [he asked] ’lt 15?’; as if he did not know what you were going to do.

In characterizing the comments we thus took into account these contextual issues to the extent that the video recordings made possible. This analysis, however, is considered in conjunction with, on the one hand, characteristic or critical real-time episodes and, on the other, a vignette taken from a series of episodes that is described in the next session.
A vignette. Suzan had had 12 years’ working experience at primary level. She had taken part in the ‘Investigations’ project from the start, and had taught third and fourth grade students during the six years of the project’s duration. She did not have a mathematics qualification more than that provided by her primary teacher's degree. She herself did not feel confident with what she termed ‘mathematics’ as an object of study. However, she believed that there is another, natural, everyday kind of mathematics from which school teaching diverts pupils to perceiving it as alien territory.

I believe that maths is in our life, in ourselves and we do it subconsciously—but someone comes and says to us: ‘look, what you were doing till now is fine, but I will teach you to do it differently like this and this and this’, so you don't do it at all and you say: ‘ah! mathematics is difficult, that's it, I cannot do it’.

Regarding the meanings she brought to the project, she did seem to make specific connections with her pedagogical aspirations to encourage cooperation and autonomy among pupils.

I thought it was very important when I was given the chance to teach them to cooperate, to make some decisions on their own and to try to understand what they are doing and why.

In describing her strategies, Suzan saw herself as offering services to help solve problematical situations already arisen. That is, when her pupils or herself have identified a problem hindering further activity, then comes the intervention.

If they call me I usually go, if they don’t I just walk around and when I see that they are stuck … I ask ‘what’s going on, what’s the problem?’

She further felt the need to ‘explain’ her directive comments and the urge to provide pupils with answers, indicating internal conflict on the issue of controlling her interventions.

Many times the answer comes out naturally, its difficult to hold yourself.

In the following episode, Suzan intervened on her own accord after a group of two third-year pupils had taken some time reiterating ‘fd 10 lt 15 fd 10 lt 5’ and at some point changing to ‘fd 10 lt 10 fd 10 lt 5’ in order to construct a planet to go with their rocket project, and after the teacher had initially encouraged them to try to make a circular planet, not letting them settle for a square one.

Teacher: Have you come to some conclusion? [yes] What?
Pupils: To make these sides lt 15 and lt 5 and those here lt 10 and lt 5.
Teacher: Ah, so not to have the same lt everywhere, ok, try it, but can you think beforehand and imagine more or less what shape will come out?
Pupils: It will not be exactly a circle. In some parts it will be rather straight.
Teacher: Ah, then it’s worth thinking about the turnings again, since here [points to screen] with these commands you don’t get large straight bits, but she goes and turns bit by bit, while with these commands you get large straight bits … maybe you should consider the commands again and instead of you getting a long eggy shape with straight bits you can get
something more round? Have a look, compare these bits which get you quite a round bit and these which do not get you much of a round bit. Don’t delete old commands, it will confuse you, yes leave them so you can check. To see, for example, what happened there, where we changed the It’s what changed in the shape? Or where our It’s were the same, what was the shape like?

The teacher’s agenda seemed to have been for the pupils to investigate how to make a circle and to progress to the ‘right’ answer, which she was clearly aware of. Reading her comments gives the impression that she was internally struggling between providing too much information and steering the activity towards constant turns. Even though she accepted constant turns (and not necessarily the classic ‘ld 1 fd 1’) as a didactical goal and attempted to not dissociate her intervention to the pupils agenda for making a planet (e.g. by referring to ‘round’ and ‘egg-like’ shapes), she seemed ‘pushed’ by the situation—time constraints, poor pupil results, lengthy lapsed time of pupil investigative inertia. She seemed to be impatient with the lack of an exploratory culture—she perceived that the pupils do not reflect, check commands against their results of the screen, compare sets of commands, enjoy hypothesizing and making an effort to make a more circular shape. So she ‘told’ them to do so, in one instance. In fact, their agenda seemed quite different from the one aspired, or expected by the teacher, and the fact that after this episode they simply ignored the comments, typed a few more commands and went on to write an essay on how great their rocket was (and not a word about the planet) is a clear enough indication. So, in attempting to encourage investigation, the teacher in effect gave a relatively large number of ‘technical directions’, hoping with this one-off intervention to influence pupil activity from then on.

**Phase 2: time units of analysis**

The first study illuminated some distinctive features of teacher interventions, indicating that although there seemed to be some resonance in the teachers’ intentions, there was a large variety in the ways in which they referred to the different aspects of the situation at hand. We felt that both of these issues, however, needed further looking into with respect to the contextual reasons behind teachers’ choices and the ways in which the classroom context influenced these. In the second study, we investigated teachers’ interventions again, this time, however, including some aspects of their social dynamics and carrying out a different analysis to gain some insight into the balance of these interventions in time. The social aspects we addressed were: (a) who initiated the intervention, (b) which social cluster it addressed (i.e. small group or whole classroom), and (c) what mode of verbal or non-verbal communication took place.

So, for example, in the following episode we worked as follows. Kate intervened through her own initiative, triggering an unrequested dialog with a group of students. Her initial intention was to supervise the students’ work. Promoting her specific agenda, she directed the pupils to construct the rectangle bar in a different way (i.e. a procedure with a variable so that they could change its length). Her
Table 3. Time—dependent analysis of teachers’ comments

<table>
<thead>
<tr>
<th></th>
<th>Martin 1 %</th>
<th>Kate 2 %</th>
<th>Peter 3 %</th>
<th>Nick 4 %</th>
<th>John 5 %</th>
<th>Average %</th>
</tr>
</thead>
<tbody>
<tr>
<td>The initiative</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Requested</td>
<td>34</td>
<td>50</td>
<td>43</td>
<td>20</td>
<td>35</td>
<td>36</td>
</tr>
<tr>
<td>2. Unrequested</td>
<td>66</td>
<td>50</td>
<td>57</td>
<td>80</td>
<td>65</td>
<td>64</td>
</tr>
<tr>
<td>To whom</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. To the whole class</td>
<td>19</td>
<td>12</td>
<td>18</td>
<td>9</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>4. To a group</td>
<td>81</td>
<td>88</td>
<td>82</td>
<td>91</td>
<td>86</td>
<td>86</td>
</tr>
<tr>
<td>The mode of communication</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Exposition</td>
<td>13</td>
<td>42</td>
<td>31</td>
<td>23</td>
<td>26</td>
<td>27</td>
</tr>
<tr>
<td>6. Dialogue</td>
<td>45</td>
<td>61</td>
<td>72</td>
<td>39</td>
<td>74</td>
<td>58</td>
</tr>
<tr>
<td>7. Resource</td>
<td>15</td>
<td>18</td>
<td>25</td>
<td>12</td>
<td>33</td>
<td>21</td>
</tr>
<tr>
<td>Non verbal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Silent observation</td>
<td>25</td>
<td>12</td>
<td>6</td>
<td>25</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td>9. Demonstration</td>
<td>3</td>
<td>25</td>
<td>14</td>
<td>0</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>The intention</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Nudge</td>
<td>24</td>
<td>39</td>
<td>34</td>
<td>10</td>
<td>18</td>
<td>25</td>
</tr>
<tr>
<td>11. Discipline</td>
<td>0</td>
<td>19</td>
<td>18</td>
<td>18</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>13. Reflective</td>
<td>38</td>
<td>18</td>
<td>40</td>
<td>9</td>
<td>29</td>
<td>27</td>
</tr>
<tr>
<td>14. Group dynamics</td>
<td>6</td>
<td>15</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>15. Motives</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>16. Procedural</td>
<td>20</td>
<td>13</td>
<td>9</td>
<td>15</td>
<td>19</td>
<td>15</td>
</tr>
<tr>
<td>17. Supervision</td>
<td>31</td>
<td>41</td>
<td>42</td>
<td>45</td>
<td>44</td>
<td>41</td>
</tr>
</tbody>
</table>

argument was both pragmatic and mathematical. Her mode of communication was exposition—explanation of the way they should do it.

Kate: Have you done the population of Athens? [means the construction of the appropriately sized bar on the chart]

Student: Yes,

Kate: Right, Well done. Now you have to do what? Oh, wait a minute. Would it be better if you put all these commands in a procedure?

Student: But it works this way Mrs.

Kate: Yes, but if you put all these commands in a procedure then you can do this thing [means the rectangle] as many times as you wish. It¡s better this way.

Student: How?

Kate: Oh come on, you know that—Get me a pencil [She goes on modeling the move of the turtle on a piece of paper explaining the steps that pupils should follow].

Table 3 presents the types of interventions in which we organized the data and the percentages of the one-minute time segments in which they appeared (we
had cases where there were more than one such type of intervention in one time interval).

Regarding the three social aspects, there seem to be some common characteristics between teachers. First, teachers’ interventions are expressed as a dialogical rather than in a directive mode (Table 3, line 6). Second, the ones made to a specific group of children by far outweigh those made to the whole class (Table 3, lines 3 and 4). The data thus seem to support, to some extent, what teachers had stated in their interviews; that is, students were encouraged to work collaboratively and the teachers intervened in order to help them and to promote their didactical agenda (Table 3, lines 1, 2 and 10).

With respect to their intentions, supervision seems to be the most frequent. Teachers appeared to intervene with the purpose to examine students’ work (Table 3, line 17) and accordingly to specify their further intervention promoting their didactical agenda. Where the diversity comes into the foreground is the way that each of them seemed to promote his/her didactical agenda, at least with respect to what they stated in their interviews.

Kate, for instance, seemed to intervene in an intensive direct mode (Table 3, column 2, line 12) and this is reflected in her mode of communication (Table 3, column 2, lines 5 and 9). Martin, on the other hand, seemed to avoid demonstration as a mode of communication and his interventions were characterized mainly by reflective rather than directive comments. In line with his espoused beliefs, he appeared to put emphasis not only on the product of the students’ activity, but also on the learning process.

I am not saying that I don’t care for the product. I do want my students to come to an end. But the important thing is that I feel now that I have more opportunities to focus on the process. This is something that we sometimes overlook and the whole experience of the ‘investigations’ brought it to the front. They [means the students] don’t expect me to tell them what to do all the time and that gives me the opportunity to focus on the process. (Extract from Martin’s interview)

In the case of Nick, the quantitative data indicate that his interventions have something in common with Kate as well as with Martin. Like Martin he tended to reject demonstration as a mode of communication, preferring instead to supervise students in a non-verbal mode by keeping his verbal interventions to a minimum. However, when he intervened he did so in a heavy instructional manner.

Student: Sir, how can we make a circle?
Student: Sir, we don’t understand how can we make a circle?
Teacher: Repeat
Student: Yes,
Teacher: 360 fd 1 rt 1

In this episode Nick approached a group of students who asked for his help. The teacher provided them with the answer right from the beginning, without any attempt to take advantage of their experience and the feedback they received
Table 4. Time dependent analysis of comments showing intent for student activity

<table>
<thead>
<tr>
<th>TEACHER</th>
<th>LESSON Comments</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Martin</td>
<td>Directive</td>
<td>6</td>
<td>21</td>
<td>30</td>
<td>36</td>
<td>19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Reflective</td>
<td>39</td>
<td>42</td>
<td>30</td>
<td>39</td>
<td>38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Kate</td>
<td>Directive</td>
<td>41</td>
<td>38</td>
<td>24</td>
<td>41</td>
<td>38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Reflective</td>
<td>40</td>
<td>16</td>
<td>28</td>
<td>3</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Peter</td>
<td>Directive</td>
<td>48</td>
<td>39</td>
<td>51</td>
<td>45</td>
<td>37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Reflective</td>
<td>30</td>
<td>48</td>
<td>32</td>
<td>19</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Nick</td>
<td>Directive</td>
<td>24</td>
<td>25</td>
<td>22</td>
<td>14</td>
<td>35</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Reflective</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>3</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>9 John</td>
<td>Directive</td>
<td>17</td>
<td>34</td>
<td>19</td>
<td>22</td>
<td>37</td>
<td>43</td>
<td>25</td>
</tr>
<tr>
<td>10</td>
<td>Reflective</td>
<td>28</td>
<td>31</td>
<td>45</td>
<td>30</td>
<td>29</td>
<td>4</td>
<td>29</td>
</tr>
</tbody>
</table>

through their interaction with the machine. He intervened in directive manner acting as an authority rather than as a counselor, indicating that probably he valued the product more than the process.

In order to explain this disparity we paid particular attention to his interventions in relation with his interview. We suggest that Nick was not convinced about the educational value of the activity. He participated not because he believed in it, but as an obligation.

I am not certain if there is any educational value in what they [means the students] are doing. Do they learning anything? I do not know.

Hence, he seemed to have constructed a practice, which to him seemed to be in line with the school demands as they can be traced in the school head’s interview who stated that: ‘what we expect from the teacher is not to teach but to investigate. Teachers coordinate the children’s work offering them their help, intervening as little as possible’.

The study of the intentions underlying teachers’ interventions indicates that there is an overall balance between directive and reflective comments (Table 3, lines 12 and 13). However, the time-dependent analysis sorting comments into one-minute segments revealed that all five teachers had the tendency to be more directive as the sequence of the lesson proceeded (Table 4).

Table 4 provides us a picture of the relation between reflective and directive comments during the whole sequence of lessons conducted by all five teachers examined. The number of one-minute units was not large enough (around 200) to have statistical significance in particular trends. However, it would make sense to say that the ratio between directive and reflective comments for most teachers seems to change in favor of the former towards the end of the project.

Comments like ‘don’t forget that we must come to an end …’, ‘Don’t waste your time …’, ‘You don’t have much time …’ and ‘You have experimented enough. You must come to an end now’ were more frequent as time passed, indicating a time pressure. Teachers had the tendency to intervene more often as they felt this
pressure, in order to promote their own agenda and ensure that students will reach a predefined end.

It seems that the need for the production of tangible piece of work that can be measured is deeply embedded in teachers’ culture and influenced their interventions heavily. One may trace here the impact of the wider educational culture. These teachers were brought up and developed professionally within a specific educational paradigm where the emphasis is on the content rather than in the process. Despite the fact that the teachers who participated in these studies had at least six years, and in most cases eight years, of experience in the ‘investigation activity’, the impact of the wider educational culture finds influenced their practice, demonstrating the difficulty to incorporate an innovation into the dominant educational culture.

**Teacher roles**

The study of the nature and intent of teachers’ interventions provided us with some insight into their practices and the ways in which they relate to their espoused beliefs. However, we felt that a lot more was going on in the classroom, which influenced the ways in which teacher and students behaved and which had to do with social roles and norms generated within the learning activity. We thus analyzed the data again from the perspective of the roles teachers adopted themselves and the ones they attributed to the students and the computers through their comments. We studied the ways the teachers organized their class, set up the tasks in which children would be engaged and how they then supported their progress. We took into account how teachers’ described their activity plans in the interviews and then what kinds of roles arose from their interventions.

For instance, we concentrated on the social interaction taking into account the verbal exchange as well the non-verbal exchange between teacher and students.

Student: Sir could you come for a minute?
Teacher: So, what are you doing here?
Student: We want to make this bar [points at their notes] but we can’t make it right
Teacher: Well. Since your turtle is here what you should tell her?
Student: To goes back
Teacher: Right, and then?
Student: …
Teacher: Which is the command you should give her afterwards?
Student: Right
Teacher: Why
Student: So as to go up
Teacher: That’s what you did previously, but it doesn’t seem to work. Does it?
Student: No, we are doing something wrong
Teacher: Now, which is the direction of the turtle?
Student: This way
Teacher: So, what should you tell her to do so as to move up?
Student: Left
Teacher: That’s right. Where is this command? You haven’t written it.

In this episode a group of students asked their teacher for his help. Peter, the teacher, approached the group and engaged himself in a dialog. The overall picture of this requested intervention reveals a teacher acting as a consultant, familiar with the problem and able to help the students. However, in each of his comments, Peter assumed a specific role for himself, the students and the computer. In one case he asked the students to show him what they did. In another, he seemed to be investigating the problem with the students, but only for an instance, mostly asking them questions intended to lead them to the solution. Then he adopted the role of authority on the mathematics at hand but not the role of resource of information. Overall, he attributed a role of representational medium to the computer, as well as a device where the students could observe what happened as part of the process of thinking about what went wrong.

Studying the roles adopted by these teachers, it was made quite clear from the beginning that it would not be meaningful to perceive them in isolation from the roles that they permitted students to adopt and the roles they offered to the computer. In the aforementioned episode, for instance, Peter formulated a consultative role in his attempt to help students interpret the feedback they received from the computer. Our point is that by attributing the computer the role of a medium providing feedback to students’ expressions, he had the time to work with one group at a time, to try to understand students’ thoughts, personalize his interventions and formulate his role.

Student 1: Miss, could you come here for a minute?
Teacher: What seems to be the problem Helen?
Student 1: It makes the rectangle in the wrong place
Teacher: Well, lets see it together. We are here and we want to go there. What should we ‘tell’ the turtle to do?
Student 2: Miss, it doesn’t work
Teacher: I am coming George.
Student 3: Miss, we’ve done it. Could you come to see it?
Teacher: Now you have to find the scale
Teacher: George I’ll be with you in a minute
Teacher: There is something wrong here. [...] You need to make a procedure to move the turtle before you execute the rectangle.

In this episode three different groups of students asked Kate for her help. While Kate approached the first group and seemed willing to work probably as counselor or fellow investigator, two other groups of students came close to her asking for her help. Kate abandoned the first group and approached the third one. She gave them a direction so as to continue their work. At the same moment she tried to ‘neutralize’ the second group by promising them that she would come to help them and returned to the original group. She intervened in a directive mode and immediately after that she went to the second group. What we see here is a teacher who struggles
to meet the needs of three different groups at the same time. This seemed to affect her practice. While her original intervention in the first group was intended to be a consultative one, finally, probably under the pressure of the other two groups, it turns to be a directive one. In fact, episodes as this were quite common in Kate’s classroom during the project, indicating that perhaps it was embedded in the classroom culture that students were allowed to contest to attract the teacher’s presence in their group so as to ensure her approval and/or guidance. Kate appeared to accept such practice taking it as granted and tried to cope with it. From this point of view it seems that the social norms of the classroom that had been negotiated between students and the teacher did affect her practice and the construction of her role.

The data thus led us to perceive the teacher’s role as a dynamic process, influenced by the situation at hand. As the data indicate, all five teachers under study tended to shift among different functions during the session.

Kate: Have you found the population of Athens?
Student: Yes,
Kate: Right, Well done. Now you have to do what? Oh, wait a minute. Would it be better if you put all these commands in a procedure?
Student: But it works this way Mrs.
Kate: Yes, but if you put all these commands in a procedure then you can do this thing [means the rectangle] as many times as you wish. It’s better this way.
Student: How?
Kate: Oh come on, you know that …Get me a pencil [She goes on modeling the move of the turtle on a piece of paper explaining the steps that pupils should follow].

In this episode, Kate initiated an intervention intending to re-direct their work. In order to do so, she demonstrated the way pupils should work. Her role changed from supervision (manager) (Table 5, line 6) to counselor (Table 5, line 8) and, finally, to instructor (Table 5, line 5).

As the table indicates, all five teachers under study seemed to devote a considerable amount of the observed segments in managing the students by adopting a supervisory role. It could be argued that such attitude reflects their attempt to maintain control of the classroom and promote their own teaching agenda, in contradiction with their statements that students were supposed to take initiatives and work in an exploratory manner.

On the other hand, although the teachers adopted a variety of roles, the most frequent were those facilitating investigational activity on the part of the students (Table 5, lines 8, 11 and 12). This was in line with their espoused beliefs expressed during the interviews. All five of them appeared to walk around the groups of students, supervising their work, offering suggestions and encouraging them to undertake an investigational role.

Student: Sir, how we will make the rectangle?
Teacher: I don’t know Peter. I suppose you don’t expect me to give you an answer.
Table 5. Time—dependent analysis of teacher and student roles

<table>
<thead>
<tr>
<th>Role</th>
<th>Martin 1 %</th>
<th>Kate 2 %</th>
<th>Peter 3 %</th>
<th>Nick 4 %</th>
<th>John 5 %</th>
<th>Average %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Students’ roles</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. spectator</td>
<td>8</td>
<td>0</td>
<td>24</td>
<td>5</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>2. transactor</td>
<td>7</td>
<td>0</td>
<td>11</td>
<td>7</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>3. investigator</td>
<td>67</td>
<td>100</td>
<td>69</td>
<td>80</td>
<td>82</td>
<td>80</td>
</tr>
<tr>
<td>4. exposition</td>
<td>21</td>
<td>0</td>
<td>18</td>
<td>16</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td><strong>2. Teacher’s role</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. instructor</td>
<td>9</td>
<td>43</td>
<td>28</td>
<td>12</td>
<td>19</td>
<td>23</td>
</tr>
<tr>
<td>6. manager</td>
<td>51</td>
<td>41</td>
<td>53</td>
<td>59</td>
<td>60</td>
<td>53</td>
</tr>
<tr>
<td>7. explainer</td>
<td>7</td>
<td>6</td>
<td>16</td>
<td>5</td>
<td>18</td>
<td>10</td>
</tr>
<tr>
<td>8. counselor</td>
<td>24</td>
<td>41</td>
<td>34</td>
<td>13</td>
<td>33</td>
<td>29</td>
</tr>
<tr>
<td>9. resource</td>
<td>9</td>
<td>14</td>
<td>18</td>
<td>7</td>
<td>23</td>
<td>14</td>
</tr>
<tr>
<td>10. warming</td>
<td>7</td>
<td>3</td>
<td>17</td>
<td>2</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>11. fellow investigator</td>
<td>4</td>
<td>12</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>12. silent observer</td>
<td>41</td>
<td>10</td>
<td>5</td>
<td>49</td>
<td>7</td>
<td>22</td>
</tr>
</tbody>
</table>

Student: ...Yes,
Teacher: No Peter. I want the three of you to cooperate and make a rectangle. I am sure you can make it. Why don’t you discuss it with the rest of the group and give it a try?

This episode is an example of the tensions the teachers had between the wider educational context and the school policy on the nature of the innovation. They seemed to be experiencing an unresolved conflict. On the one hand, they felt the need for their students to produce something at the end of the project and, on the other, they were working within a framework emphasizing the learning process, as can be traced in the school head’s interview: ‘What we expect from the teacher is not to provide students with the right answers. We want him/her to act more as a catalyst, as helper rather than as instructor’. In the earlier episode, the teacher’s first comment takes for granted that the context for refusing to provide the answer is understood. When he realized that this was far from the case, he gave a more elaborate argument of what he expected his students to do, without, however, justifying his action in relation to the students’ view of the situation.

Not surprisingly, the impact of the common social context did not seem to have had the same effect on the teachers under study. In fact, they seemed to adopt a variety of strategies to negotiate their roles.

Kate, for instance, appeared to form a role that balanced between instructor on the one hand, and counselor, as well as fellow investigator, on the other. Her role often varied from counselor to instructor or vice versa as indicated in the previous extract. It could be argued that such practice is in contrast with her espoused beliefs, where she stated: ‘I think that my role is rather a friend, a fellow investigator rather
than a teacher in the usual sense’. However, a statement that she made in one of our daily interactions during the project provided us with further insight.

We, the older teachers, tend to be more directive. We don’t leave children to act on their own, to take any initiatives. We are accustomed to intervene too much and guide them. My experience with the computers shows me that they [the students] may achieve a lot of things if I permit them a certain degree of initiative. I think that my role is changing.

Kate stated that she tended to conceive her role as rather directive and used to construct a corresponding practice. Coping with the need to explore the potential of the new technology, she had the opportunity to reflect on her practice. This experience seems to have challenged her existing pedagogical notions, affecting her beliefs. In other words, her practice reflects the impact from her initial beliefs as well as from the conceptions that had emerged from her reflection on her recent practice.

Martin, on the other hand, although he had designed the educational activity jointly with Kate, appeared to have adopted quite a different role. He acted mainly as a ‘counselor’ and a ‘silent observer’. He appeared to walk around the groups encouraging students and offering suggestions instead of guidance, leaving them to decide whether they will accept his suggestions or not.

When he intervened, he appeared to prefer to encourage students and to offer his suggestion, leaving them to decide:

Martin: I can see that you are working without using variables
Student: Yes. Does it matter?
Martin: What matters is that you don’t take advantage of the software.
Student: Well that doesn’t really matter. It’s still working.
Martin: Is it so difficult to use variables? I will help you if you want to.

[At this point a pupil from another group attracts his attention temporarily. Martin returns later to this particular group and observes their work silently without making any further comment, although pupils insist on working without using variables. In the last lesson when every group presented its work he triggered a long discussion about the use of variables and set as an example the groups that used variables in their project].

In this episode Martin engaged himself in a dialog with the group of students aiming to redirect their work so as to use variables. He did not, however, invest much in discussion and articulation of his arguments. After the students’ resistance by means of a pragmatic argument, he withdrew without further instructional comments with the apparent intention that they reflect and make their decision.

Such practice seems to be in line with his espoused beliefs:

I do like mathematics. And I think that I communicate this enthusiasm to the students. Many times before we start the daily curriculum I ask them what subject they want us to do and they select mathematics. […] I think that my role is changing. I understand it more as ‘a facilitator who provides students the opportunities to construct knowledge for themselves’. […] This is our school policy and I agree with it.
Although his discourse often lacked mathematical argumentation, as the previous extract indicates, it is in such statements and specifically in his articulated confidence that we may attribute the fact that in many instances he appeared to be ‘transparent’ (Table 5, line 12). Thus it was quite common in his practice to withdraw, keeping for himself the role of the silent observer, offering students the opportunity to take initiatives and have the privilege as well as the responsibility to decide upon their course of action. However, such attitude seemed to be in contrast with his earlier mentioned statement:

I feel that I am responsible to guide children to come to an end, to reach the right solution.

From this point of view we may argue that Martin’s practice reflects different sets of beliefs, which may exist in contradiction with one another. Such beliefs may be either conscious or unconscious, as it appeared to be the case for John.

John, alongside Martin, claimed to be quite confident with mathematics, perceiving his role mainly as ‘counselor’. Indeed his practice seemed to be affected by this view (Table 5, line 8). However, what seemed to be characteristic in his practice is intensive intervention (Table 5, column 5, lines 5–10). It seems that the need to have students reach an end affected his practice heavily. It is worth mentioning that the necessity to come to an end was stated as a main criterion for the formation of the teacher’s role by all the others teachers except John.

The classroom as a whole and the wider educational context

In the previous two sections, we identified a series of apparent inconsistencies between the kinds of beliefs the teachers seemed to have in interview and those identified during their classroom activity. We also noted that the teachers seemed to change roles in their interactions with student groups and sometimes adopt roles, which were quite different between them during the same session. We thus felt the need to investigate the classroom dynamics as a whole to complement the findings deriving from teacher intervention analysis and investigation of teacher roles in the teacher–student group–computer triad. Our attempt was to interpret the teachers’ comments with respect to the type of activity going on in the classroom as a whole and discuss that in relation to their specific views about how they planned the course during the interviews.

In Nick’s interview, for example, he seemed to believe in an intensively interactive, controlling teacher role: ‘I think that you have to know the subject very well if you are to convey it to students […] Students need to be guided’. However, in the classroom he often withdrew from action, letting students take initiatives and the responsibility to monitor their work.

John, on the other hand, seemed consistent with respect to his view about mathematics. In the classroom, he provided the students with a variable Logo procedure to work with and asked them to find out what this procedure was about. Then he asked them to experiment with it, to look for the numbers for which the shape it constructed would be a parallelogram and write down their observations. When we asked him about this activity, we received the following answer:
What I like in investigations is that I have the opportunity to do things that it would be difficult for me in the... lets say ‘traditional classroom’. I am trying to pick up subjects in relation to the official curriculum but in any case my first priority is to get students involved in activities where students would have to try things, to cooperate, to form hypothesis etc. Take for instance the subject we did the last time. I didn’t tell them the properties of the parallelogram. I gave them a procedure to play with it and discover the properties for themselves. (Extract from John’s interview)

Such statement could be regarded as consistent with the problem-solving view of mathematics according, for example, to the Ernest (1989) taxonomy. John appears to express a dynamic, problem-driven view of mathematics and to accordingly design the educational activity.

However, there are cases where teachers’ activity plans did not seem to have any direct correspondence with their beliefs; for instance, with respect to mathematics. Martin and Kate jointly designed the geography project mentioned earlier in the following way: students were asked to find out quantitative geographical information on Europe and represent it on a series of bar charts. The mathematics on the teachers’ agenda was not only representing data by means of a bar chart, but also the process of constructing the different bars (rectangles) in a sequence and finding ways with which the process would not have to be repeated for each chart. The teachers’ didactical agenda was for the pupils to suggest that they construct a rectangle procedure with one variable for its ‘height’ and then use the variation tool to create a ‘bar chart machine’ (i.e. a piece of software for creating bar charts).

In their interviews Kate expressed a view that was most consistent with the Instrumentalist view of mathematics, since she regarded mathematics as ‘facts and procedures for computing numerical expressions to find answers, something that you need in your everyday life’. In the case of Martin, on the other hand, we may trace an impact of a Platonist view of mathematics:

> What I am trying to do is not to give answers but to guide students through the right questions to find the solution. I feel that I am responsible to guide children to reach the right solution.

Although these two teachers seemed to have conflicting views about the nature of mathematics, this did not restrain them from designing their educational activity in common. It seems that beliefs about the teacher’s role and the role of the student overwhelmed their differences about the nature of mathematics. Both of them stated that they wanted their students to take more initiatives than they usually do and to experiment with the problem at hand, perceiving their own roles rather as facilitators and fellow investigators rather than instructors. Such views, which are quite common in all five teachers’ interviews, are in line with the school culture as it can be traced in the School head’s interview, who states that:

> we want to take advantage of the new technology and offer our students opportunities to foster their ability to learn, to take initiatives, to put their own problems and cope with them at their own pace. [...] We want them to work cooperatively and practice problem solving skills.
Apart from allowing students to construct exploratory roles, another main criterion for the design of the educational activities as expressed by the teachers was the relation of the activity to the official curriculum, as show by Nick and Peter’s comments:

Every now and then we discuss among us the subjects of the so called ‘investigations’. I would like every investigation to have more clear goals. In my opinion what students learn is a main criterion. (Extract from Nick’s interview)

I choose the subjects so as to have a relation to the curriculum. (Extract from Peter’s interview)

In such statements we may trace the potential impact of the rigorous curriculum and the wider Greek educational paradigm. It seems, however, that these two issues at times had overbearing importance in the teachers’ interventions than their beliefs about mathematics and mathematical learning. We thus identified cases such as the one involving Kate and Martin, where although teachers may have had different beliefs, they seemed to design the same type of educational activity. In fact, all five teachers under study designed contiguous projects, as presented in Table 6. One would expect that such variations in beliefs would reflect on their practices.

Table 6 gives us an overall description of the kind of activities, which were in the foreground during each project. On the whole, it appears that all five teachers devoted most of their time to interacting with students. They typically presented the subject in a frontal style (Table 6, line 1) and then withdrew, allowing students to assume control. Students were engaged with the problem at hand right from the beginning rather than being guided by the teacher and seemed to feel that they controlled the computer. This communication and social interaction (and the resulting noise) between children (Table 6, line 2) was not considered a nuisance that had to be suppressed, but rather as a crucial component of the whole activity as teachers appear to put emphasis on student cooperation. To this end, teachers’ discourse was not in opposition to students’ discourse (Table 6, lines 2 and 3) since all five teachers seem to encourage the students to communicate and collaborate in their groups, giving them the responsibility to make up their decisions as the following excerpt indicates:
Student: Do we have to agree on how to make the rectangle?
Teacher: You have to agree, yes. You can find many ways to reach an agreement.
Student: Can every one make his own rectangle?
Teacher: Well, this is a solution. But there are others. I think it would be better to discuss it and agree to make a rectangle as a group. I wouldn’t like to decide on this matter. It’s up to you to discuss it and find a way.

During this episode, while the teacher interacted with the specific group of students, the rest of the groups were allowed to work cooperatively in an exploratory manner. This is a typical case throughout the classrooms, as indicated in Table 6 (lines 3 and 4). This issue thus seemed embedded in the design of the activity.

One may argue that such uniformity is not surprising since, after eight years of practice in this particular school, it had been culturally embedded that during this weekly hour students should be allowed to work cooperatively in order to investigate a specific subject. Indeed, the fact that all five teachers working with different grades in different time periods designed and supported similar educational activities in contrast to the wider educational paradigm indicates that they shared the same school culture. It seems, however, that this culture incorporated social and didactical engineering aspects that, at times, had overbearing influence on individual teacher beliefs about mathematics and mathematical learning. It thus raises the question of what kinds of cultural and systemic influences are put upon teacher practices and how they cope with them with respect to their epistemological and pedagogical beliefs.

Conclusion

The study focused on the beliefs and practices these teachers had established while engaged in an innovative mathematical investigations course based on the use of exploratory software. The data itself revealed the complexity of issues, which seemed to play a pertinent role in the forming of these beliefs and practices. Each of the three perspectives with which we analyzed the data (i.e. looking at aspects of teacher interventions in the classroom, at the emerging social roles and at the possible influences of the school and the educational system) provided us with different insights. From the types of comments made by the teachers in the classroom we saw that, although there seemed to be some coherence in the kinds of activities in which they intended their students to be engaged, they referred to different aspects of the learning situations in different ways. Some of these aspects may in fact have diverted teachers’ and students’ attention away for the mathematical ideas in their investigations to issues of work management and collaboration. Furthermore, although the type of intended innovation and the use of exploratory software played a major role in the kind of mathematical activity going on in the classroom, coming up with tangible results in the given time slots was high enough in the teachers’ priorities to influence the types of interventions they made towards the end of sessions.

We also identified a variety of roles adopted by each teacher. These roles were often conflicting with respect to the meanings conveyed to the students regarding
their activities. The teachers seemed to be inevitably influenced by the classroom context, the school’s pedagogical priorities and the values within the wider educational paradigm in the Greek system. Looking at teacher plans and actions in the classroom as a whole supported our view that some social and didactical issues may have had a diverting influence on the teachers' actions, if not their beliefs, with respect to focusing on their students' understanding of mathematical ideas.

The results thus corroborate the view that espoused beliefs may be inconsistent with actions during classroom teaching practice. More than one of what we may describe as a belief system (i.e. a coherent set of views on mathematics, teacher roles and mathematical learning) may influence teachers’ practice. As we realized by approaching our data from the three distinct perspectives, one set of beliefs may look as if it is in contradiction with another, making it rather difficult to classify them according to a predefined taxonomy. The construction of these beliefs is influenced not only by the personal conception of the teacher about a subject (i.e. his/her pedagogical role), but also from the expectations that the teacher believes that others (i.e. the school head) have from him/her. This is not to say that their practices are not influenced by their beliefs. One must take into account their espoused beliefs in order to understand, explain and describe their practices. Our point is that this relation is characterized by complexity and unpredictability, and that this raises the question of how is it more meaningful to perceive teachers’ beliefs.

This research corroborates other studies in that we learn much more when looking at teacher beliefs through their classroom practice in conjunction with what they express during interviews. It raises the question, however, of whether coherent belief systems are merely constructs we as researchers may use to interpret those of the teachers rather than actually being present and formative of teaching practice. This study points us to the need for a much more open lens to the possible influences on teacher beliefs, let alone the ways in which they might influence their practice. Thus it may well be argued that innovations cannot possibly take into account the specifics of individual schools and classroom settings unless we perceive them as an integral part of the innovation. In this case, the nature of educational innovation and the ways in which it can be articulated and put into effect are in question.

Acknowledgements

Notes on contributors

Chronis Kynigos is Associate Professor at the University of Athens and Director of the Educational Technology Laboratory. For over a decade he has been engaged in research on the design and infusion of technology-based innovation in schools. His work integrates new ideas for educational artefacts with the study of learning and teaching processes in the school.

Michael Argyris is a primary teacher and holds a Ph.D. in teacher practices formed in innovative technology-based courses. He is seconded to the Educational Technology Laboratory and is involved in research and teacher education.

References


**Author Query Sheet**

<table>
<thead>
<tr>
<th>Manuscript Information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Journal Acronym</strong></td>
</tr>
<tr>
<td><strong>Volume and issue</strong></td>
</tr>
<tr>
<td><strong>Author name</strong></td>
</tr>
</tbody>
</table>

**AUTHOR:** The following queries have arisen during the editing of your manuscript. Please answer the queries by marking necessary corrections at the appropriate positions on the PROOFS. Do not answer the queries on the query sheet itself. Please also return a copy of the query sheet with your corrected proofs.

<table>
<thead>
<tr>
<th>QUERY NO.</th>
<th>QUERY DETAILS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>Text states Grand <em>et al.</em> but reference list states Grant <em>et al.</em> – which spelling is correct?</td>
</tr>
<tr>
<td>Q2</td>
<td>Explain Latseio Psychico College, Athens – is this where study took place?</td>
</tr>
<tr>
<td>Q3</td>
<td>Provide full details of Hoyles &amp; Noss (1993) for reference list or amend text citation</td>
</tr>
<tr>
<td>Q4</td>
<td>Provide text citation for Kynigos &amp; Theodossopoulou (2001)</td>
</tr>
<tr>
<td>Q5</td>
<td>Provide name of publisher for Hoyles (1992)</td>
</tr>
<tr>
<td>Q6</td>
<td>Provide city of publisher for Kafai &amp; Resnick (1996)</td>
</tr>
<tr>
<td>Q7</td>
<td>Provide names and initials of editors and name of publisher for Kynigos (1996)</td>
</tr>
<tr>
<td>Q8</td>
<td>Provide name and location of publisher for Laborde (2001)</td>
</tr>
<tr>
<td>Q9</td>
<td>Provide city of publisher for Papert (1980)</td>
</tr>
</tbody>
</table>