PROFESSIONAL KNOWLEDGE IN AN IMPROVISATION EPISODE: THE IMPORTANCE OF A COGNITIVE MODEL

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One approach towards improving teacher performance is that of classroom practice. In this paper, taking a cognitive perspective, we present a system for modelling teacher performance. We demonstrate the process of construction of this model with reference to a brief lesson episode involving teacher improvisation, which took place in the first cycle (the first four years) of primary school in Portugal. Included in the model are the cognitions made evident by the teacher as well as the relations between them.

Keywords: Improvisations, cognitions, modeling the mathematics teaching, practice, primary school

The teaching process can be analysed from various theoretical perspectives and focus on very different aspects, amongst them the teacher and their performance. With respect to classroom practice, the teacher's decisions are influenced not only by the particular context, but also, and we believe fundamentally, by his or her cognitions.

With the aim of understanding what happens in the classroom from the point of view of the teacher, in terms of both their actions and their cognitions, we decided to focus on performance, in particular the relations between the teacher's actions, cognitions and the type of communication used. The teaching-learning process is far too complex to permit a single, all-encompassing analysis, however, and hence we recognise the need for developing a model which allows it to be simplified for a more fruitful analysis. The model we developed to fulfil this aim was based on Monteiro (2006), Monteiro, Carrillo & Aguaded (2008), Schoenfeld (1998a, 2000) and Schoenfeld, Ministrell & Zee (2000). We denominate it a 'cognitive model', because it focuses only on certain of the elements comprising the system it models, in this particular case, the cognitions of the teacher with respect to their classroom practice. With this model we try to study some dimensions of professional knowledge and some relations amongst them. We hope this paper helps consider the common analysis of lessons by focussing on a limited number of variables as beneficial for researchers, trainers and teachers working in collaboration.

In the next sections we are discussing the cognitions and the kinds of communication. For the purpose of this paper, teacher's action should be identified with his/her performance in the classroom when dealing with their students' knowledge building.

The cognitions

Following Artz & Thomas-Armour (2002), we understand by cognitions all those cognitive constructions – beliefs, knowledge and goals – which each individual carries with them, the study and analysis of which, along with the relations among them, offers valuable contributions for both research and classroom practice, which can be understood as the ultimate aim of research.

As teachers we can have goals over the short, medium and long term. For Schoenfeld (1998b), goals can be simply something which one aims to attain, and can be explicit or latent, and can likewise be pre-determined or emerge during the teaching activity (Aguirre & Speer, 2000). We believe that such emergent goals especially occur in unplanned situations, particularly those which the teacher have not anticipated. We concur with Saxe (1991) that each individual – and specifically here a teacher - has the capacity to construct, adapt, model and remodel such goals in accordance with his or her own personal and professional development.

As was noted in respect of goals, so too does research into beliefs offer great potential for both theory and practice. The more we can learn about the influence of teachers' beliefs on their teaching, the deeper our understanding (Aguirre & Speer, 2000). In this study the instrument used to undertake the analysis of teachers' beliefs was that of Climent (2002). Climent presents a set of indicators of primary school teachers' beliefs (i.e., first six years in Spain) with respect to beliefs on methodology, mathematics, learning, and the roles of pupil and teacher.

Concerning our focus on professional knowledge, of particular relevance is the work, still in progress, of Ball, Thames & Phelps (submitted) which adapts Shulman's (1986) formulation for the components of professional knowledge. Further, some incorporations, namely certain descriptors from Park & Oliver (2008), are also included.

Ball and colleagues (Ball, 2003; Ball, et al., submitted), following Shulman's (1986) classification, introduce the notion of mathematical knowledge for teaching. They divide content knowledge and pedagogical content knowledge each into three categories. Content knowledge, they consider to be formed by horizon knowledge (HK), common content knowledge (CCK) – i.e., typical 'schoolboy' mathematics – and specialised content knowledge (SCK). Pedagogical content knowledge (in Shulman 'curricular knowledge'), they likewise divide into three types, each a variant of content knowledge: teaching (KCT), student (KCS), and the curriculum (KC). Hence, they maintain that teachers should have a specific professional knowledge, so that in addition to a knowledge of 'how to do' – that is, common mathematical knowledge (CCK) – they should also have a knowledge of 'how to teach to do'. Thus, for example, beyond knowing how to calculate the difference between two numbers (CCK), it is necessary for the teacher to possess an understanding which allows him or her to perceive and identify not only the students' mistakes but also the source of these mistakes, which becomes much more complex (SCK). Likewise, they should also be familiar with alternative procedures for dealing with content, so that they can easily meet the needs of their pupils. Equally, a knowledge of how the various mathematical topics relate to one other and the way in which the learning of a particular topic develops as one moves up the school (HK) is essential for the effective teacher.

As an integral part of methodological and curricular content knowledge identified by Shulman (1986), Ball, et al. (submitted) consider that teachers should possess a composite knowledge of teaching and specific content (KCT).This corresponds to the type of knowledge to which the teacher resorts in situations that are related to the organisation of different ways the students explore mathematical contents, such as: determining the sequencing of tasks, choosing examples, and selecting the most appropriate representations for each situation. Park & Oliver (2008) also include the specific strategies for teaching the content in question.

Regarding knowledge of content and students (KCS), Ball et al (submitted) relate this to the need for the teacher to anticipate what the students think, their difficulties and motivations as well as listening to and interpreting their comments. Park & Oliver (2008) include here the knowledge of the possible wrong conceptions, motivations and interests of the students, as well as their needs.

Kinds of communication

The way in which the teacher communicates with others (their students in this case) provides a great deal of information about him or herself and how they regard the whole process of teaching – including body language, level of anxiety, etc. The type of communication the teacher employs is in direct relation with the cognitions they hold, in that the way the teacher chooses to communicate reflects the way they view the teaching process. With different forms of communication, so the actions are distinct and quite possibly the underlying teaching views themselves.

We adopt the classification of Brendefur & Frykholm (2000), with some adaptations introduced by Carrillo, Climent, Gorgorió, Rojas & Prat (2008). Brendefur & Frykholm (2000) propose four types of mathematical communication: unidirectional, contributive, reflexive and instructive.

Unidirectional communication is associated with a form of teaching in which the teacher takes the principal role, requiring the student to do no more than faithfully repeat what he or she has heard. With respect to contributive communication, the student is afforded some participation in the classroom discourse, although the interactions which take place are by and large of a corrective nature and do not go very deeply into the content. The key feature of reflexive communication is that the interactions between the teacher and students act as triggers for subsequent investigative work. We agree with Carrillo et al. (2008), that development of students' mathematical comprehension is best achieved through such inquiry-based activities. Instructive communication, is similar to reflexive communication, but aims also to shed light on the matter in hand, bringing about an integration of students' ideas – progress and/or difficulties – made explicit or intuited by the teacher or by the students themselves.

The context and modelling process

The remainder of this paper is dedicated to presenting and discussing the modelling of an episode in which the teacher reviews content through dialogue. This occurs in a 4th year class given by a teacher of 18 years experience. The episode is taken from a wider research project on professional development studying the relationships between teachers' beliefs, knowledge, goals and actions. It combines a case study with an interpretative methodology whereby there is minimal intervention on the part of the researcher. Data collection – audio and video recordings of the teacher – was conducted in situ. Brief informational talks were also used before and after each lesson to gather lesson previews – lesson image – and to clarify some inferences. The video recordings provided a record of the teacher-students interactions, and enabled lessons to be viewed and analysed, as many times as required.[1] That wider research project involves a collaborative work between the researcher (first author of this paper) and two primary teachers. The collaborative work started after the first phase of data collection. It was focused in the teacher's practices mainly by discussing some situations they consider to evidence good practices and others they want to improve their **teaching**.

The first stage of the modelling process involved the transcription of the audio recordings, followed by the video (Illustration 1). Transcription also included an initial division of the lessons into episodes, defined by triggering and terminating events and associated with specific goals. Subsequently, when all the lessons pertaining to the same phase (of three in total) had gone through this procedure, there began the process of identifying the indicators of beliefs (Climent 2002), content, specific goals, type of episode, type of communication, means of working, resources used, and the teacher knowledge required for implementing the episode (Ball, et al., submitted; Park & Oliver, 2008). Also determined at this point, was whether or not the episode formed part of the lesson image (cf. Table 1).

The action sequences identified correspond to routines, scripts or action guides, and improvisations (Monteiro, 2006; Monteiro et al., 2008; Schank & Abelson, 1977; Schoenfeld, 2000; Schoenfeld et al., 2000; Sherin, Sherin & Madanes, 2000). A routine is any kind of action independent of context, executed routinely; scripts, or action guides, are specialisations of routines, but conceptually dependent. Improvisations correspond to all those actions undertaken by the teacher in response to an unexpectedly arising event.

In this study the definition of improvisation has a wider sense than that of the researchers mentioned above[2], and distinguishes two types that can arise in class. The distinction concerns the relation pertaining (or not) between the events/actions and the contents. Thus, either the action is related to the content under consideration at that moment (or which has been, or is to be, dealt with), or the action has no relation

[1] The recordings also allowed the teacher to prepare reports and to reflect more fruitfully on the various interactions between the participants through repeated viewings.

[2] They only consider situations in which the actions are unconnected to the contents. We consider that improvisations correspond to the set of teacher's actions in response to all unexpected events.

with the teaching contents, focusing only on administrative questions, student conflicts or general management issues. We call the first type (concerned with the teaching activity) ‘content improvisations’, and those of the second (concerned with classroom management) ‘management improvisations’.

It should be noted that content improvisations constitute episodes which do not form a part of the lesson image and which necessarily have emergent goals. Because such episodes have not received prior consideration, the teacher’s cognitions come very much more to the fore since their response is so much more intuitive. Content improvisations are consequently one of the points in which cognitions are most in evidence.

A teaching episode and its analysis

In this section we present a transcript of an episode from the first of a series of four lessons aimed at introducing the concept of ‘a thousandth’. Given that the transcript illustrates a goal in emergence, the episode cannot be considered to form part of the lesson image. The extract shows the teacher taking the opportunity presented by a student doubt to revise, via a whole-class dialogue, the difference between squares and rectangles through reference to the lengths of the sides.

246	S	This isn’t a rectangle, it’s a square . . .
247	T	Is this shape a rectangle or not?
248	S	No!
249	T	So, why isn’t it a square, Tiago Luís?
250	S	Because the sides aren’t the same length.
251		I thought it was a square, Miss.
252		(Inaudible)
253	T	Paulo quiet.
254		What features does it have it have to be a square?
255	S	It has to have the sides the same length.
256	T	The sides all the same.
257	Ss	(Inaudible, everybody speaking at the same time)
258	T	(Puts hand up)
259		Quiet, quiet, put your hands up.
260		(T points to one of the sides of the square)
261		Paulo, if this side is twenty-five squares long, and this side is … how many?
262	Ss	Forty!
263	T	Forty … so, is it a square?
264	S	No!
265	T	Why not, Paulo?
266	S	Because the sides aren’t the same length.
267	T	Exactly.
268	S	To be a square it has to be twenty-five by twenty-five.

Illustration 1 – Transcript of an excerpt from the first, of a series of four, classes aimed at introducing the concept of ‘a thousandth’, corresponding to an improvised content revision dialogue (T: teacher; S(s): student(s))

This excerpt corresponds to the ninth episode in the first lesson of the first phase of work [I.1.9]. The triggering and terminating events coincide with the start end of the transcript. The teacher's emerging goal is to revise the difference between squares and rectangles in terms of the lengths of their sides. The communication type she employs is contributive, with the students working in a large group (the whole class).

The coding within the square brackets indicates that the lesson takes place during the first phase (pre-collaborative work) and corresponds to the ninth episode of the first lesson [I.1.9]. The left-hand box provides information on the specific category to which each indicator of beliefs belongs (in brackets) in addition to the goal and knowledge which have been identified, the triggering and terminating events, the type of episode and whether or not it forms part of the lesson image. The right-hand boxes record the sub-episodes ([I.1.9.1], [I.1.9.2]) along with their specific goals and the kind of dialogue involved.

[I.1.9] Dialogical revision of content - difference between squares and rectangles - in a contributive way, with the whole class (246-268)[3]
Forms part of the lesson image? No.
Triggering event: T asks whether shape is a rectangle or not.
Indicators of beliefs[4]:
TT30 (**Teacher's role**) – The teacher is the one who validates ideas raised in class, questioning students, whose replies lead to self-correction (in reality veiled correction, stage-managed by the teacher).
TR16/TT16 (**Learning**) – The student interacts with the material and the teacher, the latter being the mediator between material and student. The interaction produced between teacher and student is unequal, with the flow teacher-student being stronger than the contrary.
Goal: Revise difference between squares and rectangles (length of sides).
Knowledge:
CCK (**Common Content Knowledge**) – Knowing the difference between squares and rectangles (in terms of the length of the sides).
SCK (**Specialized Content Knowledge**) – The teacher gives evidence of an incorrect use of the classification of polygons (using a disjunctive classification implying that the set of squares is separate from that of rectangles)
KCT (**Knowledge of Content and Teaching**) – The teacher considers contributive dialogue appropriate for the revision of the difference between the length of the sides of squares and rectangles.
KCS (**Knowledge of Content and Students**) – The teacher considers that the students show difficulties in considering squares as specific cases of rectangles (246-250), (254-256)
(GAP: the teacher does not perceive this difficulty of considering squares as rectangles as she uses disjunctive classifications and an incomplete definition of squares focused exclusively on the properties of the sides (forgetting the rhombus), which could generate erroneous conceptions (256).)
Type of episode: Content improvisation.
Terminating event: T considers that the students' doubt has been clarified.

[I.1.9.1] T holds a dialogue with the group, and contributively revises the difference between the relative lengths of the sides of squares and rectangles (246-260)

Interactive dialogues (246-260)
Specific goal: Revise the difference between the relative lengths of the sides of squares and rectangles.

[I.1.9.2] T holds a dialogue with the group, and contributively clarifies that, by virtue of its sides not all being the same length, the shape cannot be a square (261-268)

Interactive dialogues (261-268)
Specific goal: Clarify that a rectangle is different from a square as one has sides of all the same length and the other does not.

[3] Line numbering of transcript.
[4] This episode reveals beliefs concerning methodology (TR3, TR5), the role of the teacher (TT26/29, TT30) and learning (TR16/TT16, TT14), where TR denotes Traditional Tendency and TT Technological Tendency.

Table 1 – Modellisation of an episode corresponding to the ninth episode in the first of four lessons introducing the concept of a thousandth

This episode did not form part of the teacher's lesson image as it arose from a student comment. In the course of enacting the episode the teacher employs two actions which, from the analysis we have carried out until now, form the basis of all the revision episodes, independently of the resource(s) used, the form of work and the type of communication. It should be noted that, for this type of episode, these actions do not have to occur in the same order as in this specific case and that these are the only two kinds of actions the teacher does when she wants to implement this specific type of episode in this particular manner.

Relations between cognitions

The evidence for the teacher's cognitions is obtained from their actions, the kind of communication which occurs, the form of work of the students and the resources used. The table below illustrates the relations observed between the actions and cognitions in respect of the specific goal in this case. Some of the teacher's knowledge (to the right of the table) are relevant to the whole episode while others are specific to particular actions.

<table>
<tr><th>Indicators of beliefs/contributive language</th><th>Actions</th><th colspan="2">Knowledge/contributive communication</th></tr>
<tr><td>TT30 (Teacher's role) – The teacher is the one who validates ideas raised in class, questioning students, whose replies lead to self-correction (in reality veiled correction, stage-managed by the teacher).</td><td>T holds a dialogue with the group, and contributively revises the difference between the relative lengths of the sides of squares and rectangles (246-260).</td><td>KCS (Knowledge of Content and Students) The teacher considers that the students would have difficulties in considering squares as specific cases of rectangles (246-250), (254-256).</td><td rowspan="2">CCK (Common Content Knowledge) – Knowing the difference between squares and rectangles (in terms of the length of the sides).
KCT (Knowledge of Content and Teaching) – The teacher considers contributive dialogue appropriate for the revision of the difference between the length of the sides of squares and rectangles.</td></tr>
<tr><td>TR16/TT16 (Learning) – The student interacts with the material and the teacher, the latter being the mediator between material and student. The interaction produced between teacher and student is unequal, with the flow teacher-student being stronger than the contrary.</td><td>T holds a dialogue with the group, and contributively clarifies that, by virtue of its sides not all being the same length, the shape cannot be a square (261-268).</td><td>SCK (Specialized Content Knowledge) – The teacher gives evidence of an incorrect use of the classification of polygons (using a disjunctive classification implying that the set of squares is separate from that of rectangles).</td></tr>
</table>

Table 2 – Relations between actions and cognitions with respect to the revision of the difference between squares and rectangles, in terms of the lengths of their sides, via a contibutibutive whole class dialogue.

The actions of revising and clarifying the content are underpinned by beliefs related to the role of the teacher (TT30) and to the learning process (TT16). The cognitions identified show that the teacher regards herself as the only person with the capacity/ability to validate the information mobilised in class. In viewing her role in this way, she conditions the interactions between other elements of the process of learning, thus preventing a balance being reached among them and making it impossible to achieve a triangle of learning, as advocated by Pinto & Santos (2006). These actions/beliefs are linked to each other in such a way that together they form the basis of all revision episodes.

The knowledge identified, as well as the gaps in knowledge, are specific to the situation and the context, and so cannot be generalised, not even for this teacher.

Possibilities for initial and in-service teacher training

This type of analysis may also be of use in initial teacher training as the starting point for an approximation between theory and practice. It would mean that researchers and teachers "speak the same language", using the same codifications; in doing so, a great degree of collaboration is needed.

This type of analysis (by student teachers in their teaching practice), although based on the experience of others, may lead to an awareness of their own cognitions, of the way they relate and influence one another. This awareness would help the development of a critical, as opposed to submissive, attitude during their teaching practice; merely observing the mentors does not necessarily lead to learning (Brophy, 2004). It is important, then, that the time spent in schools by trainee teachers as observers or assistants should be given careful consideration and attention.

In the sphere of in-service training, this type of analysis can be effected by the teacher him or herself, who, in watching recordings of their lessons, will be able to reflect upon their own practice (Schön, 1983, 1987). This reflection, accompanied by discussion and critical exchanges with colleagues and researchers, can be considered a first step towards sustained professional development (Climent & Carrillo, 2003; Jaworski, 2006) aimed at improving professional competence through qualified professional reflection (Hospesová, Tichá & Machácková, 2007).

We selected content improvisations as the focus of our analysis because, when they occur, the teacher "is working without a safety-net". They are unforeseen situations not subject to advanced planning, and consequently all the teacher's cognitions come into play in their purest form, faithfully reflecting their mode of acting and their position with respect to the process and intervening elements. It will be in these situations that, in the initial stages of training programmes as in professional development, significant information can be obtained which can contribute to the development process, enriching discussion and leading to a self-awareness of one's professional attitude. These situations can permit access to what Tomás Ferreira (2005) terms 'teaching modes', underlining the relationships between their dominant classroom interaction, teacher's key beliefs and in this case, also their professional knowledge.

This analysis and understanding are very important now that there exists in Portugal a Programme of In-service Training in Mathematics for teachers of the 1st and 2nd cycles of Basic Education with a supervision component (Serrazina et al., 2005). One of the ways of achieving some of the goals of this programme – deepening teachers' mathematical, pedagogical and curricular knowledge and encouraging a positive attitude in teachers towards mathematics and the capabilities of the students – could involve the analysis and discussion of teachers' classes, through the use of this cognitive perspective and of the model.

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