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Trabajo de Investigación Tutelado

An Exploration of Teacher Enactment of CSCL Activities in Computer-Integrated Classrooms

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Executive Summary

The growing presence of digital technologies in the classroom and the need to find innovative uses for these technologies poses a challenge for teachers at all levels of the educational system. Teachers are provided with increasing amounts of hardware and software, and they are asked to realize the dream of an innovative, computer-integrated classroom. *Computer-supported collaborative learning* (CSCL) activities have been posed as a response to these needs, but their enactment is complex and burdensome for the average teacher. *CSCL scripts* are a popular method of alleviating this burden, supporting teachers in the *orchestration* of tasks, tools, and groups of students, by structuring the flow of the activity. However, in the enactment of CSCL activities, teachers also have to *react* to the feedback of students and to other *unexpected events* that may render the script ineffective.

This document is intended as an *exploration* of the issues and problems that teachers face when they enact *CSCL activities* in a *computer-integrated classroom*, in order to inform the *design of CSCL tools* that support teachers in the flexible enactment of such activities. This exploration combines a review of *existing literature* on the main aspects of the problem with a prospective *analysis of enactment* with an exemplary CSCL tool (GroupScribbles), also complemented with an *exploratory fieldwork* conducted in several computer-integrated classrooms at a Spanish primary school, using the same tool.

Drawing from existing models of teacher enactment and from data gathered in the field, an *extended teacher model* is proposed in which several intrinsic factors of teachers (their knowledge, goals, beliefs and emotions) interact with the context and its constraints, to produce the teaching practice (e.g. design and enactment of activities). This teacher model is then integrated with concepts derived from the study of CSCL literature on enactment issues (such as improvisation, orchestration and the need for flexibility), to form a *conceptual framework* that accounts for the main notions around the phenomenon of teacher enactment. The need for *flexible* tools and the *pattern-based* nature of improvisation and enacted orchestration emerge as central concepts in this framework.

This conceptual framework, along with the analysis of the affordances of GroupScribbles from the enactment point of view, is used to propose a number of *recommendations* for the design of CSCL tools: to take into account both the intrinsic characteristics of teachers and the peculiarities of the classroom context; to uncover and exploit improvisational and orchestration patterns, by allowing teachers to mix and match them in real time; and to fusion design and enactment in a small set of simple actions and metaphors. Finally, the document details a list of foreseeable *future steps* in

a design-based research to take place at the aforementioned primary school, in order to develop tools and training methods to foster flexible enactment of CSCL activities.

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Chapter 1

Introduction

> *Claire speeded up along the school corridor. She was running a bit late and, even if the kids would be taken care of by another teacher, she hated when lessons ran short and she had to break in the middle of an activity. But, she reassured herself, it had been necessary. This was one of those classes where she would have to use the computers, and she had had to plan everything carefully. No surprises. Technology provided enough of them already. It made her feel as if she was a novice teacher again, and every class held up a bunch of (not always pleasant) surprises for her. Claire changed her notebook to the other hand in order to grasp the door handle and opened the door of the class, releasing the voice of the other teacher while it mounted over the background noise of children chatter.*
>
> *Twenty minutes later, the other teacher had left and Claire was already deep into her lesson. At the beginning, everything was going according to the plan: some explanation, followed by question/answer turns and, after that, a (prepared in advance) web search. However, something had started to go awry. The kids had not understood one of the key concepts. She thought of doing another web search, or looking into the school's repository of activities for something that could help her. But no, it was too risky, and she didn't want to break the flow of the class [...] In the end, she pulled it off just by falling back to using her voice and a bit of her teaching experience. But, as she watched the kids staring attentively to the screen, she wondered whether this power for captivating their attention could be harnessed somehow...*

Even if it is just a narrative dramatization, Claire's tale of teaching with technology is based on true facts and characters, and it exemplifies nicely some aspects of the current situation in many classrooms: the increasing presence of information and communication technologies (ICT) in schools,

the central role that teachers play in the coordination of a classroom, the technical knowledge and points of view of teachers regarding technology, or the need for improvisation in the enactment of everyday teacher practice and how teachers cope with it. The Tutored Research Work[1] presented here revolves around many of these issues.

Governments and educational institutions have been announcing the investment of massive amounts of money in new digital technologies since their first appearance more than twenty years ago [Pla06, MdE09, PJ05]. These technologies have been introduced in our schools, first in the form of dedicated computer labs (which are still very popular in Spanish schools) but also, increasingly often, integrated into ordinary classrooms [Pla06]. This trend, as well as the emphasis in the latest investment programs about portable devices such as laptops and netbooks [MdE09], hint at the rise of the so-called *computer-integrated classroom* [BBB+02, HBZ93]. However, despite this long-standing effort to modernize our schools, the benefits of their widespread use in education are still unclear [Cub01].

It has been said that technology alone cannot produce benefits without a change in educational methods [Sni92, Cub01, Saw06]. There are, however, educational reforms under way, such as the Bologna process [Dec99]. Even if these reforms have other primary goals (e.g. to unify the European Space for Higher Education), an increased *usage of digital technologies* and a change in the pedagogic methods towards more *collaborative learning processes*, appear in these reforms among the tools that will shape our educational systems in the near future [RR09].

A way to respond to these needs for the incorporation of digital technologies and new educational methods is through *computer-supported collaborative learning* (CSCL), a research field which "focuses on technology as a mediational tool within collaborative methods of instruction" [Kos96]. CSCL's richness and complexity can be found in its duality. It is at the same time a theoretical research field and a practical one where researchers, teachers, developers and evaluators work together. We believe that the inherently multidisciplinar nature of the scenario depicted above matches the multiple facets of CSCL.

Thus, let us go back to our (computer-integrated) classroom, which has been transformed into a complex technological ecosystem with a wealth of digital resources intended for learning [ZF03], and let us look at it *from the point of view of CSCL*. In an ideal case, taking full advantage of these resources would involve educational designers, developers, system administrators, evaluators and practitioners. All of these actors would be experts in each of their fields, able to fine-tune the curriculum, the activities involved and their implementation in class, both from a pedagogical and from a technological point of view.

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[1]TRIT being the Spanish acronym (TRabajos de Investigación Tutelados)

Today's classrooms, however, are very far from this rosy picture and, rather, look more like Claire's opening vignette: very often *it is the teacher who designs, enacts and evaluates the activities* that are conducted in class, struggling "to get the time necessary to reach their educational objectives" [Dil09]. Moreover, teachers also play a very important role in the classroom, even in a collaborative one, because of their extensive knowledge of the classroom context (e.g. the school, its environment, peculiarities of each of the students), customizing in many cases the activities to this context, in order to provide a more meaningful learning experience [Gim88].

Educational practice can be grossly divided in several *phases* [Jac92, Doy79], which do not necessarily happen sequentially, but rather cyclically or in an intertwinded way [JAS09a]: a *design* phase, in which the teacher plans ahead of time the flow of the class, and which tasks (collaborative or not, technology-supported or not) the students will have to complete in order to achieve the educational goals; an *enactment* phase, in which the actual lesson takes place; and an *evaluation* phase, in which the designed and enacted classes are assessed in order to improve the teaching practice (e.g. for the next time the course is delivered). Even if teachers believe in the *importance of good planning and design* (as we saw in Claire's tale, and as we will see later on with real data), it is widely accepted that *it is the activity in its enacted form what shapes the learning experience of students* [PSG07]. And this enactment, despite any support by other specialists in the design and evaluation phases, will be mainly done *by teachers* alone.

This document describes the Tutored Research Work of the author with the aim of **exploring the enactment of CSCL activities in computer-integrated classrooms**, in the GSIC-EMIC group at the University of Valladolid. The GSIC-EMIC[2] [Gru08] is a multi-disciplinar research group, formed by engineers, computer scientists, pedagogists and psycho-pedagogists, which is mainly interested in the application of new technologies in education, and specially in the field of CSCL. This research group is interested in developing CSCL environments, supporting educational practitioners in the different phases of their practice, both through technological tools (such as [BLGSVG+08] or [HLVFAP+06]) and educational processes (see, for example, [JAS09b]). This Tutored Research Work is part of a wider effort of the GSIC-EMIC group towards the *design and implementation of learning environments that support teacher's enactment of CSCL activities*, including not only the technological means, but also the pedagogical ones.

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[2]Which is the Spanish acronym for Intelligent and Collaborative Systems Group – Education, Media, Informatics and Culture

1.1 Exploring teacher enactment of CSCL in computer-integrated classrooms

Once we have established the importance of teacher enactment of CSCL activities in computer-integrated classrooms, and that our ultimate goal is to design and develop tools and processes that support this enactment, let us briefly describe *how* this goals may be achieved, that is, which methodology will be used in the research effort that frames this document. Afterwards, we will look at the main problems and issues in this kind of scenarios, and how they will explored throughout this document.

The study suggested here is not a simple endeavor, since a computer-integrated classroom is a *complex* learning environment, in which traditional forms of communication and media (e.g. speech, blackboard, paper) may co-exist with digital media (e.g. web content, tablet PCs, digital whiteboards), serving different functions [KJHH05]. Trying understand and support the enactment of CSCL activities in such environments brings in the additional complexities of trying to make learning *collaborative*. Moreover, if we plan to make the results of our research applicable to "real world" scenarios, we should comply with several additional constraints [Dil09], which basically can be summarized as: do your research in real contexts, taking into account the constraints of real scenarios, and how your results can be sustained after the research work is over. One popular methodology in the realm of CSCL that fulfills these requirements is design-based research[3].

Design-based research [Bro92, CJB04] brings a design and engineering approach to the learning sciences, by systematically studying a learning scheme within a set of concrete contexts (which have been previously designed by the researcher), usually in a series of iterative cycles of theorizing, designing changes, implementing them in the real context, and evaluating the results. This whole process often includes multiple interventions during long periods of time (usually several years). The aim of this methodology is to understand particular learning ecologies and developing and testing theories about them, and how and why they work the way they do. Figure 1.1 (adapted from [Ree06]) represents the flow of design-based research, when compared to predictive, hypothesis-driven (or logical-deductive) research.

In our case, we propose to conduct a *design-based research effort* with the aim of engineering *learning environments* in order to support teachers in the *enactment of CSCL activities*, as a followup to GSIC-EMIC's work in supporting teachers in the design of such activities. This document represents the first exploration of the concepts and issues that will be designed

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[3]As an example of this popularity, many of the works presented at the latest CSCL2009 conference used design-based methodologies, and several panels discussed different aspects of this methodology (see, for example [Dil09, Hc09, HZTS09, NS09]). Moreover, many of the endorsers of the Design-Based Collective [Col09] are influential researchers in the field of CSCL.

Predictive Research

| Hypotheses based upon observations and/or existing theories | → | Experiments designed to test hypotheses | → | Theory refinement based on test results | ⇢ | Application of theory by practitioners |

specification of new hypotheses

Design Research

| Analysis of practical problems by researchers and practitioners in collaboration | → | Development of solutions informed by existing design principles and technological innovations | → | Iterative cycles of testing and refinement of solutions in practice | → | Reflection to produce "design principles" and enhance solution implementation |

refinement of problems, solutions, methods and design principles

Figure 1.1: Diagram representing the flow of design-based research and predictive research

and engineered later on during this research on enactment. But... which issues should we explore and how should we do it?

As we saw in Claire's opening vignette, one of the main processes that teachers follow during the enactment is to monitor the environment of the classroom (e.g. to assess whether students understand the concepts) and to *take the necessary decisions and actions* to manage the flow of the activities [PG88, Sch99]. In order to support teachers in the enactment, we need to understand how this decision process works, that is, *why teachers act the way they do* during the enactment.

Moreover, the practice of CSCL involves by definition two additional sets of problems, when compared to traditional I-R-E[4] lessons. On the one hand, it involves the *usage of ICT technologies* during the enactment, as Claire did during her lesson. Even if these technologies are not used to the exclusion of other tools (e.g. pen and paper), it can be very important to know how technologies get integrated into a classroom, and specially *how teachers appropriate these technologies*. This issue can be particularly important when working in authentic educational settings, as it happens in design-based research.

The second set of additional problems comes from the collaborative na-

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[4]Initiation/Response/Evaluation

ture of CSCL activities. Monitoring and subtly guiding the interactions of students along different activities, using different tools (digital or not), in order to produce the kind of interactions that lead into useful collaboration [DJF09], and doing that in real-time during a lesson, is no small task. One popular way of supporting teachers in this process of *orchestrating* tools, activities and groups of students is through the usage of scripts of well-known collaborative best practices to model and to guide the design of CSCL activities [WKD+09][5]. These scripts can provide guidelines of different granularities, from individual utterances in a conversation (micro-scripts) to large activity phases (macro-scripts) [DH08]. *Understanding the process of orchestration* of CSCL activities (either scripted or not) will also be very important for our endeavor of supporting teacher enactment in CSCL.

However, as the old saying goes, "the best plans of mice and men often go astray" [Ste37], and the plans of the teacher, either highly detailed or very general, are always put to test when the class is enacted. It is in the *enactment* phase when things start to go bad: technological tools break down, students fail to show up in class, or react unexpectedly to the teacher's planned class flow [DT07]. Sometimes uncertainty itself is embedded in the teacher's plans, even if in an implicit way [Sch99] (e.g. if the teacher is unsure of how one task will work out), making the process of teaching sort of contingent [Int08]. Thus, in our research we should also aim at *understanding the issue of flexibility in the enactment* of CSCL activities, if our designs are to be used successfully in real classroom scenarios.

Also, since our long-term goal is to design tools that support teachers in the enactment of CSCL activities, we should also take a look at the technological side of the enactment issues. Thus, it will be relevant to *understand the role and influence of tools* (specially, ICT tools, but also looking for synergies with non-digital tools) in the enactment of CSCL.

Finally, we should not forget that we pretend our research to be applicable to real contexts (and, in fact, design-based research mandates the *intervention* in real contexts). Thus, our inquiry on teacher enactment should also include a *exploratory field study in authentic computer-integrated classrooms* (preferably, the same one that is going to be "engineered"), in order to get to know its context, and foresee any problems or advantages that working in that context could bring about. This kind of pilot work can also be very useful for the formation of the first "humble theories"[6] in a design-based research [CCd+].

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[5]Although authors are not unanimous in this regard, see [Sfa98] for a counter-argument.
[6]As opposed to "grand theories" like e.g. constructivism

1.2 Goals and structure of the document

As we have established so far, the main *goal* of the research work presented in this document is to **explore teacher enactment of CSCL activities in computer-integrated classrooms**, in order to inform the design of CSCL environments that support teachers in this process. Figure 1.2 represents this goal, the context and the problems from which it was derived, and how we have tried to accomplish it throughout this year's work.

As we can see in the figure, in order to explore the issue of teacher enactment of CSCL activities in computer-integrated classrooms, we have decided to decompose our exploration into several smaller goals:

To understand the process of teacher enactment in computer-integrated classrooms. This in itself is not a simple goal, and we have decided to approach it from several points of view, by doing a review of educational literature about how and why teachers enact their classes the way they do (by exploring existing *teacher models*), and by reviewing existing literature on *computer-integrated classrooms* and the *appropriation and integration of ICT* by teachers. However, this understanding would be incomplete if we stopped at literature review, and thus data is also drawn from an *exploratory pilot study* done by the GSIC-EMIC group in several computer-integrated classrooms in a primary school in Cigales (Spain). In this study, a CSCL tool (GroupScribbles [SRI08]) was introduced in the classroom to see how it affected the design and enactment of teachers. The election of this concrete tool for our study was motivated by its affordances for flexibility and improvisation [RTC⁺07], and because the group had prior experience with it [DAPHL⁺07].

To understand the main issues in the enactment of CSCL activities by exploring past literature in that field regarding how teachers *orchestrate* CSCL activities, tools and groupings, as well as by exploring the need for *improvisation and flexibility* that teachers have in everyday practice of CSCL. Here again, the literature review has been complemented with the data gathered in the aformentioned *pilot study* in a real primary school.

To propose a conceptual framework for CSCL enactment in computer-integrated classrooms to be done by fusioning all the aforementioned data and understandings about the different aspects of our setting into a unified model that can help us explain why teachers enact the activities the way they do, and that will guide us in the design and implementation of our interventions in the real context. As we will see later, the concept of *patterns* is ever-present in many of these concepts, as it is the need for *flexibility* in any tool that intends to support everyday teacher enactment.
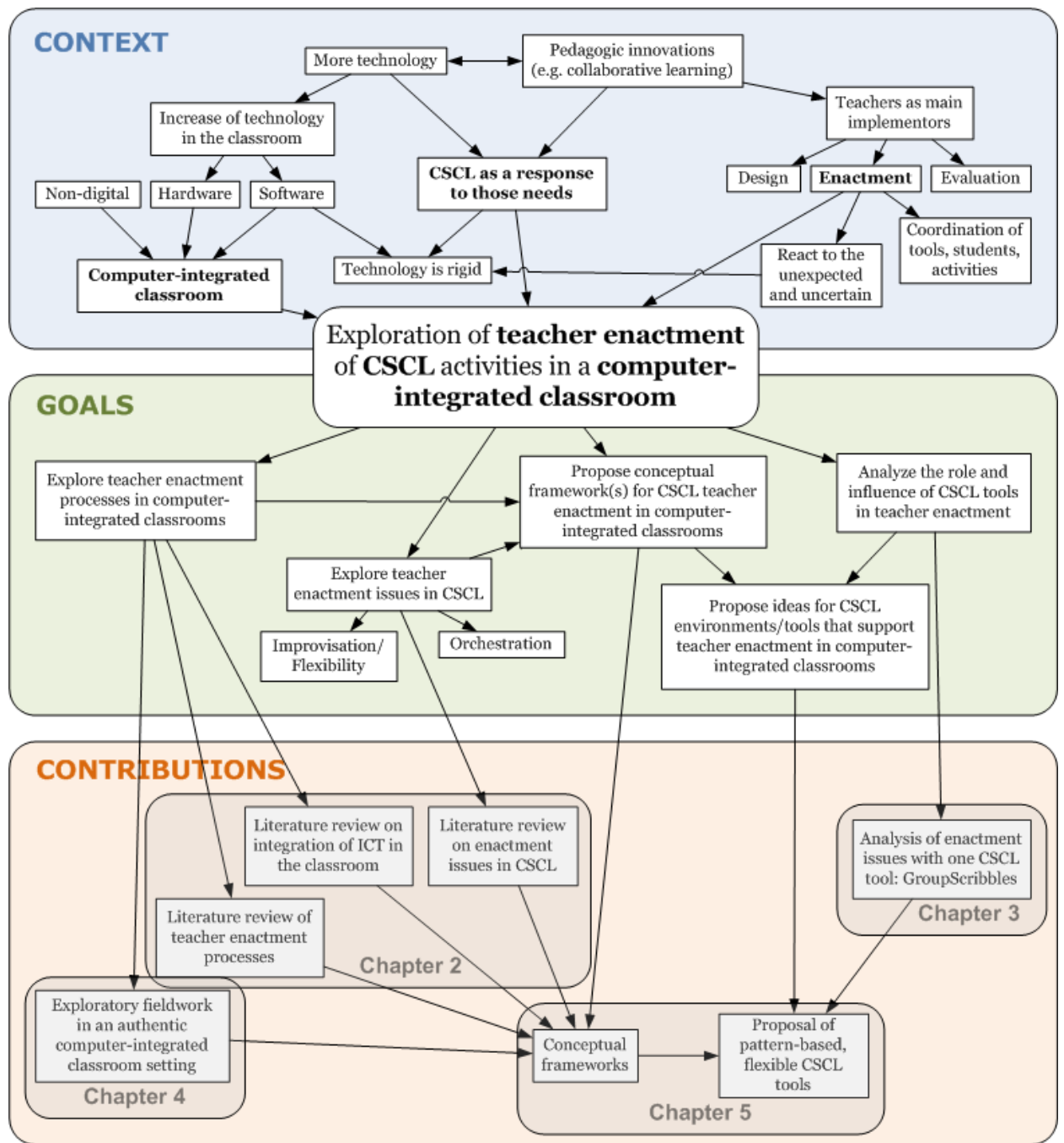
Figure 1.2: Diagram representing the context, goals and main contributions of this document

To understand the role and influence of tools in CSCL enactment.
Since our aim is the design of technological artifacts that can support the

enactments of teachers, it is important that we take into account how the design of the tool affects the issues of enactment that we have presented so far. We will take some steps in this direction by describing *one example application* (the aforementioned GroupScribbles application) and analyzing it from the point of view of the enactment issues presented so far (orchestration, flexibility, etc).

To make proposals about CSCL tools and environments taking into account the concepts presented in this document, specially the concepts of patterns and that of flexibility. This will be done both within the context of the primary school studied, but also for other contexts, paying special attention to potential relationships with existing projects and lines of research at the GSIC.

In order to show the advancement towards these goals, the rest of the document is structured as follows (see also figure 1.2):

Chapter 2 contains all the *literature reviews* mentioned so far, including the study on *teacher models* of enactment, the *integration of ICT* in the classroom and its appropriation by teachers, as well as the revision of the issues of *flexibility and orchestration in CSCL* activities.

Chapter 3 contains a brief introduction to the concept of CSCL tool and the different kinds of CSCL tools that exist, to the concept of affordance, as well as approaching the *analysis of CSCL tools in enactment* through the example of the *GroupScribbles* application.

In Chapter 4 we can find a summary of the *exploratory field work* that took place in several computer-integrated classrooms in a primary school in Cigales (Spain), using GroupScribbles. It focuses specially in the description of the concrete context of the school, as well as the main findings observed regarding teachers' activity design and enactment.

Chapter 5 tries to bring together the literature reviews and the empyrical data gathered in Cigales, in order to draw a comprehensive *conceptual framework* that can guide us in future design-based research efforts in that school. Also, *proposals* will be made for the creation of CSCL environments that support teacher enactment in computer-integrated classrooms, as well as modifications to existing tools and implications for other research lines at the GSIC.

And finally, chapter 6 will summarize the main *conclusions* of the document, and will outline *future steps* to be taken in our research, specially concerning our intervention in Cigales.

Chapter 2

Teacher enactment in literature

As the reader may remember, the goal of this document is to explore the process of teacher enactment of CSCL activities in computer-integrated classrooms, in order to design CSCL environments that support this enactment. We have decided, in the spirit of *user-centered design* [ND86], to aim at *understanding the task* that our user (the teacher, in this case) is trying to accomplish. However, the task of enacting a CSCL activity is a very complex one, and it cannot be described or studied easily, since it is dependent on the concrete context of each classroom, the curriculum to be enacted, as well as the myriad of unexpected occurrences that may happen during this enactment.

As a first step in this journey of exploration, a review of existing literature on the subject is in order. To approach such a complex topic which, as far as we know, has not been specifically treated before, we have tried to decompose the situation into its main aspects, in progressively fine-grained topics:

- **Teacher enactment**: In order to understand the general nature of the phenomenon of teacher enactment, and specially to understand the mental processes of teachers when they perform such enactment, we will review existing literature and try to arrive to a *teacher model* that can guide us in the comprehension of this classroom phenomenon, and in the design of tools and interventions that support this process.

- **Enactment with ICT**: Even if teachers have been enacting classes for centuries, it is only in the last years that the have had to face the introduction of ICT in their classrooms, and the novelty of such tools (aggravated by their continuous evolution and changes) can prove a determinant factor of the success or failure of a CSCL tool. Thus, a study on *how teachers integrate and use ICT* in their classes, specially

in computer-integrated classrooms, should also illuminate us in our future designs.

- **Enactment of CSCL**: Enacting a CSCL activity is a complex challenge for any teacher, regardless of technical expertise or professional experience. Even if we could leave aside the hurdles that digital technologies often impose, the *orchestration* of different tasks being performed by different groups of students, using a variety of tools and media, can be overwhelming. *Scripting* activities can serve as a crutch to hold on to in these cases, but coping with emergent behavior and unexpected events may be impossible, if the script is not *flexible* enough. A review of CSCL literature on these issues of orchestration and flexibility will be an indispensable tool in our comprehension of teacher enactment of CSCL.

This chapter contains the results of these three literature reviews, which will also be invaluable in the interpretation of the exploratory fieldwork that took place in a primary school in Cigales (Spain), and which appears in chapter 4. Yet, the reverse is also true, since the observation of a real context can prompt us to modify the general conceptualizations that emerge from these reviews. With these aims in mind, the following sections are organized along those three axis, beginning with the models of teacher enactment, then a brief review on the subject of the integration of new technologies in the classroom, and finally defining two of the main phenomena in CSCL enactment: orchestration and flexibility.

2.1 Teacher models: How (and why) teachers enact their classes

There is a wealth of literature (specially in pedagogy, but also in psychology and linguistics) describing *how* teachers conduct their lessons, under a variety of circumstances, and in a variety of subject matters and pedagogical paradigms (see [BL89] for some examples). This kind of studies, coupled with an exploration of a concrete educational context (such as the one depicted in chapter 4), can help us understand the process of teacher enactment, and design tools that support this process.

However, knowing *how* teachers act in class is not as useful for our design-based research purposes as knowing *why* they do it so, and having some kind of model of the teachers' enactment processes or, to put it the other way around: a *teacher model*. This kind of explicative framework would allow us not only to design tools that match the teacher's processes, but also to design our interventions in a more effective way, by matching the theory with the concrete educational context that we wish to work on.

2.1.1 The Teacher Model Group (TMG): Knowledge, goals and beliefs

The Teacher Model Group (TMG) at Berkeley tried to model complex behavior such as the one observed in the enactment of math lessons, in order to build a theory of teaching that produces analytic models of teachers' classroom behavior, trying to capture how and why teachers make the decisions they make in the midst of their teaching [Sch06].

This model, developed in a series of papers (see [Sch99] for more references), modeled several tutoring and teaching episodes. Basically, the TMG shared Lampert's view of the teachers working towards multiple goals at once [Lam01], thus defining a goal-driven architecture, in which *decision making is a function of teachers' knowledge, goals and beliefs*. These goals can overlap one another at any certain moment, and may include short-term goals (e.g. have students learn the concrete content of this lesson), medium-term goals (e.g. create a supportive climate in the class) or long-term goals (e.g. aiding the intellecual and personal developement of students). Furthermore, these goals are shaped by the teacher's beliefs and values.

Thus, the teacher enters the classroom with a set of goals, and with some plans (either explicitly written or implicit in the teacher's mind) to achieve them. If something unusual happens during the class, a decision is called for, which can change the goals operating at the moment, and/or their respective priorities [Sch99].

The authors of this theory also suggest a number of practical applications for it, including professional development of teachers (since it explains how and why teaching is done), as well as the revelation of routines and discourse patterns common to very different teachers, and which could be taught to novice teachers [Sch02]. Even if these patterns do not take into account collaborative learning, the idea of teachable/learnable patterns for teachers could be useful in the design of our interventions towards a better computer-integrated classroom enactment (since these interventions will most probably include some form of professional development of teachers).

2.1.2 Ernest's model: Knowledge, beliefs, attitudes... and context

Ernest [Ern88, Ern89] proposed a teacher model in which the *teaching practice is related to the knowledge, beliefs and attitutes* of the teacher. This model, which was also born in the field of mathematics teaching, has been applied to elementary teaching [Wil08], and thus it could be adequate for our research, which includes interventions in primary school scenarios.

In Ernest's model, the concept of knowledge included subject matter knowledge, pedagogy and curriculum knowledge, as well as classroom management and knowledge about the context. Under the beliefs tag, we find

concepts about the subject matter, teaching methods and general principles of education. Finally, attitudes include affective characteristics towards the subject matter as well as towards teaching itself.

A specially interesting feature of Ernest's teacher model is the distinction between *espoused* (the beliefs professed by teachers) and *enacted beliefs* (the ones that derive from the teacher's behavior), deriving from numerous case studies. The disparity between these two kinds of beliefs can be explained through the powerful influence of *social context* (e.g. the curriculum, the educational system, the expectations of students, parents, etc), which imposes a set of *constraints* to their teaching practice, regardless of what the teacher thinks about education.

2.1.3 Other teacher models

When reviewing existing literature about teacher models for the enactment of lessons (the term "teaching practice" being commonly used as well), it is striking how many of these models feature the concept of *beliefs* (either about the subject matter, or about teaching and learning) as very prominent in the models. The TMG's or Ernest's models are just two examples, and another one can be found in [BD08]. This model places just two factors in the forefront: *knowledge and beliefs*, and how they relate with teacher's practice.

In literature we can also find other models which are not centered around the teachers' beliefs. For example, Freeman [Fre89] posits teaching as a decision-making process (very much like the TMG view of teaching), but in this case his model is based on the concepts of *knowledge, skills, attitude and awareness*, and its immediate goal was to guide teacher instruction, i.e. teaching how to teach. In this model, knowledge includes subject matter knowledge as well as student and context knowledge. Skills, in turn, are the practical side of teacher's knowledge base: the ability to present material, to give clear instructions, etc. Attitude is quite abstractly defined by Freeman as the stance one adopts towards oneself, teaching and the learners, and has an emotional component to it. Finally, awareness is the capacity to recognize features of the classroom situation.

2.1.4 Summary of the teacher models

Figure 2.1 summarizes the teacher models of enactment reviewed so far. Instead of choosing one model and ditching the others, we will try to synthesize a number of informed assertions about a suitable teacher model of enactment, based on the presented material:

- Two concepts seem central to most teacher models, and should therefore be taken very seriously when trying to predict or modify teaching in the classroom: *teacher's knowledge and beliefs*. Any attempt to
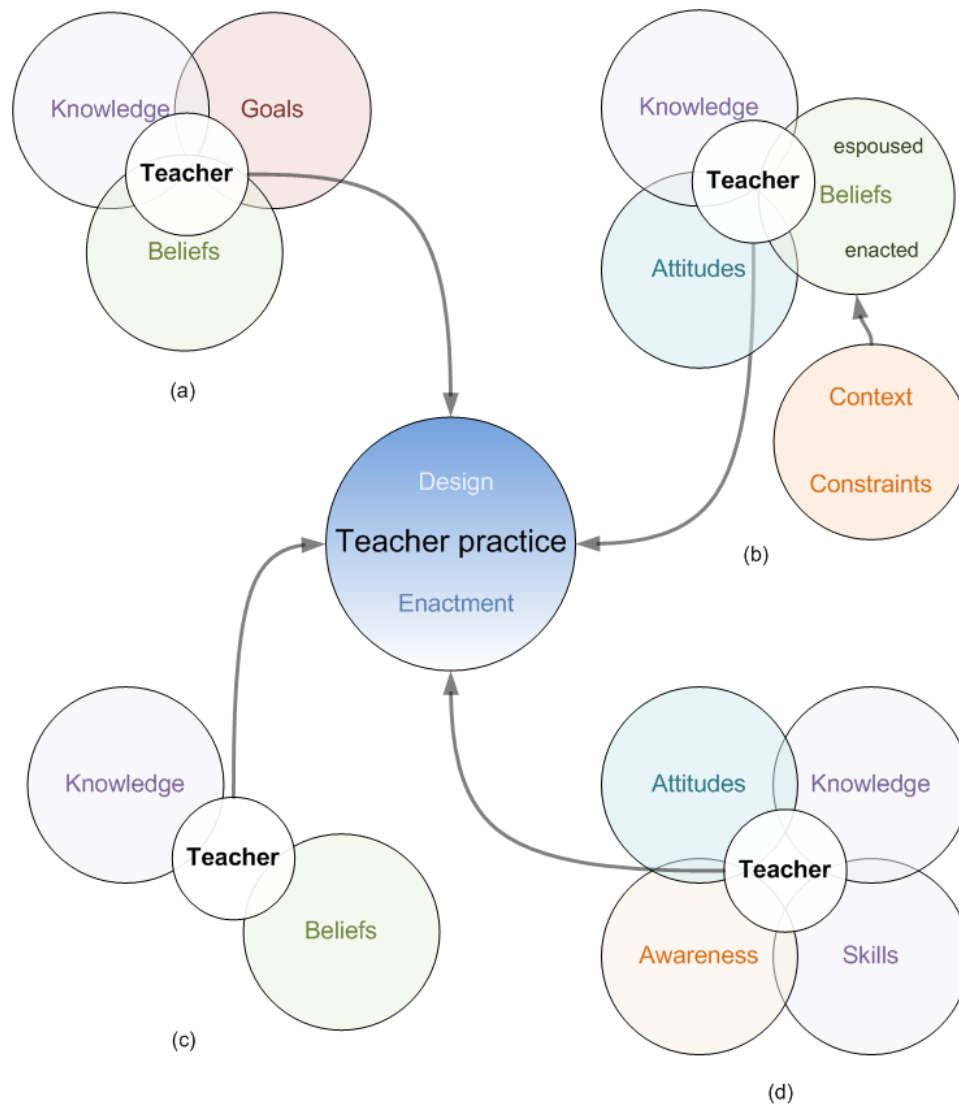
Figure 2.1: Diagrams representing different teacher models: (a) Teacher model from the Teacher Model Group, (b) Ernest's teacher model, (c) Beyer's teacher model, (d) Freeman's teacher model

modify an educational context should take them into account, and maybe even try to act on them, if we want those modifications to be sustained after the research.

- The *goals* of teachers are also a important part of the teaching process: this includes not only the curriculum, but also other, more fine-grained goals that the teacher may have (probably motivated by the knowledge and beliefs).

- Even if knowledge, goals and beliefs are very important to the teaching process, we must also take into account that *teachers may not be consciously aware of them* at all times [Ern88], and that sometimes teacher's routines may appear to support beliefs or goals that have not been expressed explicitly. Currently it is unclear how this could affect our research.

- There is another factor that has not been looked at deeply in the mentioned literature (even if it is mentioned, in both the TMG and Ernest's works), which is that of the concrete *context* of the classroom and the *constraints* it imposes on the teacher's decisions. This context includes everything from the educational system of the country to the location and educational culture of the school, the characteristics of the students or the resources available to the teacher. Taking into account these contextual constraints will enable us to better understand why teachers act the way they do.

- Finally, and even if it does not appear in all models, we should not ditch completely the concept of attitudes or, at least, the *emotional factors* that could also affect teaching. We should avoid the caveat of thinking that teachers are perfectly logic entities that act according to purely intellectual models, and thus we should also remain open to "emotional design" issues [Nor03].

2.2 Enactment in the computer-integrated classroom

2.2.1 The computer-integrated classroom

After reviewing some of the most relevant theoretical frameworks that are applicable to the enactment of lessons, it is time to take a look at the educational setting where it is going to happen, the so-called *computer-integrated classroom* (CiC). By defining it and reviewing some of the most relevant works about integration of new technologies in the classroom, we will not only gain insights on which theories could be more useful in our research, but also about *how* they should be applied to this concrete educational setting.

The concept of computer-integrated classroom was first put forward by Hoppe [HBZ93], who envisioned the classroom of the future as one in which *traditional forms of communication and media* (e.g. speech, blackboard, paper) *may co-exist with digital media* (web content, tablet PCs, digital whiteboards), *serving different functions* [KJHH05]. This concept has a lot to do with "invisible computers" [Nor98], ubiquitous computing or roomware, which basically advocate for the usage of computers with the naturalness of any other everyday object, to achieve immediate, specific tasks.

Even if much of the vision of CiC has to do with integrating computing abilities into classroom appliances and experimenting to make novel hardware (such as interactive tabletops [Sco03]), after sixteen years, computers are still slowly arriving to the real classrooms, and under a quite recognizable forms: laptops, tablet PCs or digital whiteboards. Thus, our emphasis will not be so much on novel ways of human-computer interaction and ubiquitous computing, but rather on *the usage of the existing digital and non-digital tools that we can find in the school classroom* (e.g. in the concrete context that we are studying, the Cigales school, see chapter 4).

With this point of view in mind, it will be very useful to understand, not only the technological side of the tools that are to be used in enacting the lessons, but also the psychological/human-factors side of the problem, i.e. how teachers cope with changes (and specially with technological changes) in their classrooms. Since our design-based approach will probably call for pedagogical (as well as technological) changes in the classroom, this kind of understanding about the integration of changes can be doubly useful for us.

2.2.2 Coping with technological change: Integrating ICT in the classroom

There exist a number of research studies addressing the problem of how teachers cope with changes in the classroom. Specially, since the advent of digital technologies with educational applications, there have been many studies on the subject of how to integrate these new technologies in the classroom, as painlessly as possible.

One way of modeling this process of integration is using what Ertmer called *first- and second-order barriers to change* [Ert99]. In this model, there are a number of barriers that must be overcome before teachers integrate successfully new technologies in their classrooms. First-order barriers are *barriers that are external to the teachers*, such as the lack of equipment, lack of training, lack of technical support, etc, which impede the adequate implementation of the technologically enhanced environment. On the other hand, second-order barriers are internal, often rooted in teachers' underlying beliefs about teaching and learning, and how they should look like. Thus, technologies that just automate existing processes could be integrated just by overcoming first-order barriers, while other technologies would require tackling both types of barriers, if they prompt fundamentally different ways of teaching and learning (e.g. CSCL activities vs. traditional I-R-E lessons).

For many years it was assumed that, once first-order barriers were overcome, the integration would automatically follow. Experience, however, has taught us otherwise [Cub01], and we should consider carefully how each technology is going to be put to use in an educational context, specially regarding the teacher's belief and value systems, if we want them to be used effectively by teachers.

One interesting view on the subject of why technology is not used more widely in schools is provided by Zhao and Frank, by analyzing the classroom from an ecological perspective [ZF03], a metaphor that tries to account for the complexity and sheer number of factors that affect this problem. In their work, the computer (or, rather, a *computer use*) is an "alien species" in the classroom environment, and its survival and dissemination is determined by its adequacy to the ecosystem, Darwin's old "survival of the fittest". This view of the classroom also puts emphasis in the *central role of the teacher* in this ecosystem and in the adequation of new species to the environment, designating it as a "keystone species". Figure 2.2 depicts the main concepts of this metaphor. In order for the invading species to survive, two sets of factors must be taken into account:

- The qualities of the species (i.e. the computer use): longevity (that is, if the computer use can be sustained enough time to propagate), fecundity (how easy it is for a computer use to pass from one teacher to another) and copy-fidelity (the modifications or mutations that the computer use suffers as it spreads[1]).

- The *interactions* of the species (i.e. the computer use) with the environment. In the classroom, one of the main interactions is represented by the *perceived cost-benefit of the computer use* by the teacher (e.g. costs of using it, educational benefits, etc). The *adequacy* of the computer use to the classroom ecosystem (e.g. is the new computer use compatible with the current ecosystem, its social values, beliefs, resources...?), is also crucial to the use's survival, as it is the *compatibility* with the "native species", that is, whether synergies (or symbioses, to follow the biologic metaphor) with current technologies and their uses can occur.

Other authors have also studied instances of attempts of integrating ICT technologies into the classroom. Kanstrup, for example, highlights the importance of teachers as "gatekeepers" and main implementors of any ICT integration in the classroom [Kan03]. She also characterizes the work of teachers as an *improvisational choreography* [WWH02] (an expression that will sound rather familiar to the reader by now), and the problem-solving with ICT is seen as some sort of bricolage [Str68] or reflective conversation [Sch83] with materials, since they do not solve problems by reading the manual, but rather by the exploration and reflection of different options and theories.

We will end this brief review of analyses of ICT integration in schools by mentioning the work of Staples, Pugach and Himes in elementary schools

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[1]It is unclear if it is better to have a high or a low copy-fidelity. Probably, the creators of the technology want it to be used as they designed, but it may well be that other uses are more suitable for the users.
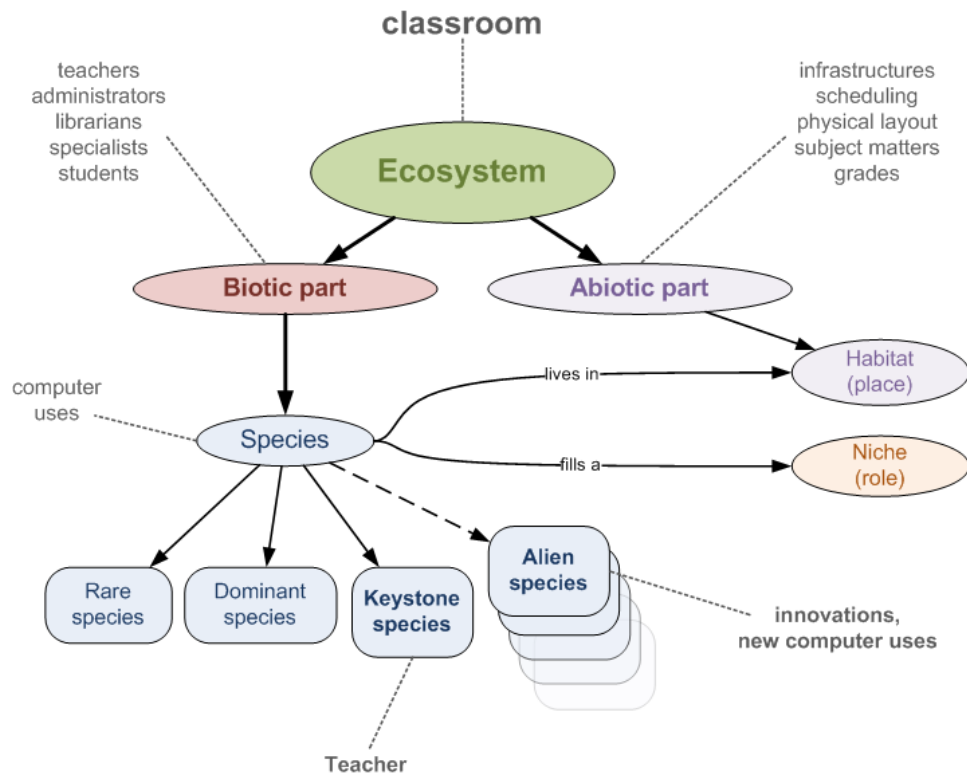
Figure 2.2: Diagram representing the metaphor of the classroom as an ecosystem

[SPH05]. The results of their qualitative research are mostly compatible with what has been presented so far: the importance of *teacher leadership* in the adoption of technology, the need for technology uses that are *aligned with the curriculum*, and how the *private and public roles of technology* are ackowledged (e.g. if the use of technology, both by teachers and by students, is recognized and rewarded).

2.2.3 Summary: Integrating our research in the classroom

The definition of the computer-integrated classroom, and this brief review on the study of how technologies are integrated in the classroom, point us towards several directions in future attempts to modify this complex educational ecosystem:

- In all the studies we can observe the central role of the teacher as the main gatekeeper of technology adoption, as the "keystone species" in the complex ecosystem of the classroom. Thus, the *teacher-centered* focus of the research presented in this document seems to be an adequate one to ensure an easy integration.

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- It is also notorious how *teachers' beliefs and perceptions* also made their way into most of the models and studies about technology integration. Consequently, taking into account (and eventually trying to modify) those perceptions and beliefs should be a matter of utmost importance in any future intervention in school contexts, which should not stop in the implementation of any technological solution, but be combined with adequate training and exposure to the technology, and its pedagogical uses.

- Finally, it may be striking the low importance that technology itself (e.g. the hardware and software) is given in these studies, compared with the importance of *computer uses*. This indicates that, in order to successfully integrate the technology, usability and human factors, the process of the usage for teaching and learning, will be crucial, rather than striving for system efficiency or performance.

2.3 CSCL enactment phenomena

After reviewing several theories that try to explain how and why teachers act in class the way they do, and how they integrate technology in their practice, now we will concentrate on the enactment phenomena that derive from the specific nature of CSCL and CSCL activities, and specially from one of the main tensions present in such enactment: scripting vs improvisation [DAPHL+07, Tat07, Dil02].

2.3.1 The improvisational nature of enactment

The concrete form that teachers' enactment of classes take (e.g. the words used in the discourse, the gestures, etc), as it occurs with everyday conversations, is not predefined to the last word in advance, but rather it is largely *improvisational* [Saw01]. Despite some attempts to "teacher-proof" education by scripting the lessons down to a very low level (almost word-for-word [SE01, Eng80]), the plans for the most exhaustively prepared lesson usually remain at a higher level of abstraction than the final enactment. Thus, the element of improvisation has always been present, in one way or another, in the art of teaching [Saw04b].

Improvisation as a metaphor for teacher discourse in class has been around for quite a long time now, for example in the writings of Erickson [Eri82] and Yinger [Yin87]. These writings use the concept of improvisation to study and develop discourse strategies and classroom discourse *patterns*, extracted from the practice of *expert teachers*, that can be useful in the education of novel teachers. In fact, much of this interest in improvisation comes from the fact that expert and modellic teachers are known to improvise more

(and more effectively) than novel teachers [BL89, Yin87], producing more *open-ended plans* for their lessons than their novel counterparts.

In the last decade, there has been a renaissance of the interest about improvisation and teaching. For example, Humphreys draws strong parallels between *teaching and jazz improvisation* [HH02], and conceives the teacher as being similar to a jazz soloist. For him, teaching appears as an intuitive performance within a planned, mutually understood framework. Humphreys goes on to assert that, as a consequence, teaching involves the acquisition of a number of skills, including flexibility, intuition, spontaneity and creativity. In the same musical vein, it has also been said that improvisation can be seen as a form of *real-time composition*, a mutually recursive process between the performer, the instrument and other performers or actors [HB95] (e.g. the sound coming from the instrument, and from other performers, affect the playing of the instrument, and its sound affects the subsequent playing, etc). This idea of improvisation as "composing in real time" draws relationships between the design and the enactment of teacher practice (i.e. enactment could be seen as a lightweight, rapid form of design).

Other improvisational forms of art have also been compared with teaching. For example, Sawyer advocates for a greater use of improvisation in education, as well as training teachers with techniques developed in *improvisational theater* [Saw04b]. Sawyer proposes this increase in improvisation on the grounds of education being the responsive, interactive activity of a teacher working together with a unique group of students. The efforts in exploiting this parallelism with improvised theater techniques, however, have obtained mixed results [SD08] (e.g. teachers had to break many of the improvisational theater "rules" in order to teach effectively, probably because of the different goals and structure of the classroom when compared to improvisational theater).

As Brown and Edelson put it, teaching is *disciplined improvisation*, "a dynamic process involving a combination of planning and improvisation" [BE01]. It is disciplined because it occurs within some level of structure and framework. In fact, expert teachers are known to use more routines and activity structures, i.e. *patterns*, but combined in a more creative way. This concept of *patterns* [AIS77] *as a basis for improvisational conduct* is well established in literature [BL89, Sud93], and will be central in our later discussion.

Thus, we could think of any lesson as being at some point in a *continuum between structure/script and flexibility/improvisation*[DAPHL+07], between a totally scripted, teacher-proofed lesson [Goo01] and a totally improvised one [Saw04a].

2.3.2 Orchestration, scripting and flexibility

As we have seen, any teacher enactment involves a certain amount of improvisation and structure. But let us go back to CSCL practice. Even if CSCL puts great emphasis in the learning of students, and specially in the learning that involves collaboration among students, most CSCL practice is very far from being "teacherless". In fact, there is a common understanding that effective teaching and learning not only should include peer interactions, but also individual work and whole-class activities [Dil09]. This fusion (or, rather, sequencing) of *activities* occurring at *different social levels*, coupled with the fact that most classrooms (either physical or virtual) allow for many *different kinds of digital and non-digital tools* to be used to support the learning processes, prompts us to think of teachers as conductors, *orchestrating*, subtly guiding the activities of different groups and using different instruments to achieve the common goal of learning.

Orchestration has been proposed as a metaphor for classroom interaction, defined as the work of "arranging things to achieve a desired effect" [Hou00]. The parallels are obvious if we consider that teachers have certain pedagogical goals, decide what will be the flow of the class, and also decide when the lesson is over [FA02, KKS01]. Thus the assertion of teachers "orchestrating classroom discourse" [JC05].

This kind of orchestration, as it happens in the musical case, has two facets: it is *planned* before the performance by an orchestrator who defines who will play each part of the score (i.e. in the design phase of the activity), but it is also *performed* by a conductor (i.e. in the enactment phase). Yet, we have to be careful with this musical metaphor, since music can range from the rigidness of classical music (where conductors can only exert a limited range of variations e.g. in speed, volume, expression) to the flexibility of jazz improvisation (where there is no orchestration or conductor to speak of, and musicians have almost complete freedom).

In the field of CSCL, the concept of orchestration has been put forward by Fischer and Dillenbourg [FD06], defining it as the capacity of teachers to "productively coordinate supportive interventions across multiple learning activities occurring at multiple social levels" [DJF09]. That is, their capacity to deal with activities occurring at different social levels (individual work, small group work or class-wide work), using different tools and media (computer-based activities, paper-based activities, video, audio) and in different learning contexts (at school, during field trips, at home, etc).

Unfortunately, the phenomenon of teacher orchestration during enactment has not been thoroughly studied, and most of the references to it are too brief or too abstract to posit a theoretical framework or a model for it. We can, however, look at this orchestration from the point of view of *learning design*. In CSCL, a common way of supporting teachers in the complex labors of orchestrating a collaborative activity is through the use of *scripts*.

The concept of *script* in education was originally derived from the teaching as performance metaphor [Gag78, Del95], which viewed teachers as performers, actors that played a pre-defined script, represented in many cases by the textbook. It is also tied to the psychological concept of scripts in everyday life, meaning the mental representation of procedures we use in common situations, such as entering a restaurant or participating in a business meeting [SA77]. When applied to education, and specially to collaborative learning, scripts can be defined as *methods that structure face-to-face (and computer-mediated) collaborative learning* [OD92, KWD+07].

In the research on CSCL, scripts have been a popular way of structuring collaboration among participants of a learning scenario, in the quest for interactions that foster learning, such as argumentation, explanations or mutual regulation [DH08, WFM02]. Scripts, however, can be defined at different levels of abstraction, and thus can be classified into:

Micro-scripts Dialogue models which students are expected to adopt and internalize, e.g. by prompting a student to respond to a fellow student in a certain way, with a counter-argument. These scripts typically span only a few minutes of class interaction.

Macro-scripts Pedagogical models that sequence the activities to be performed by groups or single students. These scripts are more coarse grained, and can span a whole lesson, or even several days of instruction[2].

In their function as a support for the orchestration of CSCL activities, scripts normally are specified as a *sequence of phases*, each of them characterized by the following *attributes* [Dil02]:

- *Type of task* to be accomplished

- Student *group formation* and composition

- *Distribution of the task* among and within groups, including the different *roles* of the participants as well as the *tools* to be used in completing the task.

- *Type and mode of interaction*, e.g. co-located vs. remote, synchronous vs. asynchronous, text-based vs. voice based, etc.

- *Timing* aspects of the phase

Other ways of specifying and conceptualizing a script are also possible like, for example, the one presented in [KWD+07], which characterizes a

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[2]Since macro-scripts are most helpful in the large-scale management (or orchestration) of classroom enactment, we will from now on concentrate on this kind of script, referring to them simply as "scripts".

script through its *components* (participants, activities, roles, resources and groups) and *mechanisms* (task distribution, group formation and sequencing). In fact, collaboration scripts have been formalized in order for them to be machine-understandable (see, for example, the IMS-LD specification [Con03]), and CSCL systems have been implemented that use such specifications (e.g. the Collage/Gridcole system described in [DHL04]).

However, as we have seen, most effective teaching involves a balance between structure and improvisation. In fact, even if CSCL scripts have obtained positive results in fostering effective learning in certain situations, they have also been criticized for offering a too rigid support [DT07], which could render them ineffective in the face of unexpected events that often occur in the classroom. Thus, there is also an increasing interest in adding *flexibility* to this kind of scripts, so that they can be modified during the runtime of the activities.

One possible approach to implementing this kind of flexibility in macro CSCL scripts is to analyze the scripts and separate the *intrinsic constraints* of the script (i.e. the characteristics that are crucial for the useful interactions to occur) from the *extrinsic constraints* (the arbitrary implementation decisions that make up the rest of the script, and which could be changed without the script losing its sense) [DT07]. Ideally, the runtime of the script should allow the modification of these extrinsic constraints, while leaving the intrinsic part of the script unchanged. Several approaches have been proposed in order to add flexibility to collaborative scripting systems in CSCL, some of which will be reviewed in the following section.

2.3.3 CSCL tools that specifically target flexibility and orchestration

The following are three examples of CSCL systems and tools that appear in literature, targeting the specific problems that we are focusing on, namely flexibility and orchestration in enactment of CSCL lessons. They are intended as a snapshot (rather than an exhaustive account) of the field of CSCL systems that allow for flexible enactments.

Adaptive Collaboration Scripting (ACS)

Adaptive Collaboration Scripting (ACS) is a framework for adding certain flexibility features to a scripting engine, proposed by Demetriadis and Karakostas [DK08]. The framework follows the aforementioned concepts about the separation of intrinsic and extrinsic constraints [DT07].

ACS tries to *adapt the execution of a script* automatically (during its runtime, but also in its design, instantiation and setup), in order to account for a number of different events, such as user characteristics and (extrinsic) script characteristics. Thus, for example, this framework would allow for

on-the-fly changes in group formation (e.g. if students fail to show up), in the deadlines of activities, or by providing additional support to novice learners that need extra scaffolding. In this work, *flexible* design, setup and enactment tools are necessary in order to *adapt* (i.e. to optimize) the activity to the circumstances of the classroom, most of which are known in advance, but which may also be emergent.

The implementations of this framework so far are fragmentary, covering only one script at a time. As a complement to the framework, a prototype method (DeACS) has also been proposed, in order to uncover *adaptation patterns* (specific, recognizable ways in which a script can be changed, when triggered by certain events) that may be used in future implementations of the framework [KD09].

Anticipating flexibility through assessment

A different perspective in the addition of flexibility to scripted environments is the one proposed in [VFHLAP$^+$09]: The main idea is to embed assessment activities into the script, which can act as triggers for conditional enactment of parts of the script. For example, if the assesment activity indicates that insufficient knowledge has been gained by a group, an additional task (which was included in the design, but had been hidden up to that point) would be made available to that group.

This proposal exploits a concept related to that of flexibility, which some authors have called *contingency* [Int08]. In a contingent class, the teacher embeds conditional avenues for the activities, specially if the outcome of a phase is uncertain. Contingency (as well as other flexibility features in scripting) is supported by formalized learning design languages, such as IMS-LD [Con03]. However, the complexity of implementing it has derived into partial, non-standard implementations in the different IMS-LD compliant script environments.

The prototype implementation of this system involves the combination of the Collage authoring tool [HLVFAP$^+$06] for designing the script, and the Grail IMS-LD player [dCdlFVG$^+$07] and a Wiki for its enactment. Currently, the execution is not fully automatic and, in fact, requires deep knowledge of the tools and the IMS-LD specification for the flexibility mechanisms be used.

WikiPlus

Another recent attempt to provide a more flexible CSCL system, but from a very different perspective, is the one proposed by Doebeli and Notari [DN09], using a *modified version of a wiki* [CL08b] to regulate learners' activities. They called this kind of system a WikiPlus. This system allows teachers to adapt the script whenever non-predicted learner activities come to happen.

A prototype of this WikiPlus concept has been implemented, based on Twiki [Tho09]. Basically, its aim is to extend the basic functionality of a wiki (basically, to let non-technicians generate static web content) towards something more dynamic (to *allow non-technicians to define processes*, in this case, learning processes). In this kind of systems, technical knowledge is still required to generate *wiki templates that represent a macro script* (see chapter 2). Later on, the teacher instantiates the script by filling in the template, and finally students and teachers enact the script.

The distinguishing features of this WikiPlus system, according to its authors, are the fact that it can be *used by teachers* with relative ease (as opposed to many scripting environments, which require specialized technical and pedagogical knowledge), its ability to accomodate rapidly *any kind of script* (many scripting environments only support a limited variety of scripts) and, specially, its ability to be modified on runtime (i.e. *flexibility*) without specialized help.

2.3.4 Summary: How to help improvising and orchestrating

To summarize this review that started by noticing the improvisational nature of all teaching, and led us all the way to the orchestration of different educational tools, scripting and its flexibilization, we can take a look at the concept diagram shown in figure 2.3. Furthermore, we can draw a number of conclusions that can help us in our attempts to ease the problems of the teacher enacting a lesson in a CSCL classroom:

- As we have seen, most effective teachers combine structures and routines with a creative, improvisational use of those structures, in order to achieve their educational goals. The definition of those *structures*, at different levels, and how they can be *mapped to the educational goals* could be very valuable not only to novice teachers but also for experimented ones.

- The coarse granularity and the *implicit* nature of many of the teachers' goals and structures clashes with the levels of *formalization* that most computer-based systems require. It could be argued that free-form, unstructured computer systems such as wikis could be a useful tool in bridging the gap that exists between the concreteness of computers and the *flexibility* required to face the myriad of unexpected circumstances that could arise in a classroom.

- The emphasis put so far in developing adaptive CSCL systems that allow for the flexible enactment of scripts, adapting themselves automatically to the context of the activity is specially useful in distance, computer-mediated lessons, where the system has access to most of

Figure 2.3: Main concepts and relationships in the enactment of CSCL activities

the information about the interactions. However, in a face-to-face environment such as a computer-integrated classroom, where much of the information and communication happens *outside of the computer systems*, it is probably better to trust the perceptual powers of teachers,

and strive for flexible systems that can be *adapted under the teacher's demands.*

- The usage of CSCL macro scripts can help teachers in orchestrating their activities across different social levels, by defining the workflow of the lesson. It is necessary, however, that teachers understand which are the *goals of the script* and the *role* that each of its parts play in attaining those goals, in order to assess the progress of the lesson, and eventually modify this workflow if it is deemed necessary, during the enactment.

- Regarding the orchestration of different tools, it is very important that the teachers know *which tools* they have at hand. Also, the *affordances* of those tools, and the *goals* that could be achieved with them, should be brought to the teacher's attention in order to foster effective use. The degree of *confidence* that teachers have with each tool could be another factor to have in mind in this tool orchestration (since it defines the perceived affordances and uses of the tool for them).

Chapter 3

CSCL tools for enactment: the case of GroupScribbles

So far, we have introduced the context and goals of our work (to explore the situation of teacher enactment of CSCL activities in computer-integrated classrooms), and we have reviewed some of the most relevant educational literature about that process. However, since our aim is *technological* (the design and implementation of CSCL tools that support this enactment), we should not neglect the technological side of the picture: the role of CSCL tools themselves in the enactment, that is, *how the design of the tool affects teacher enactment* of the activities.

In order to explore this relationship between the tool and the enactment, this chapter will first give an overview of what we understand by "CSCL tool", and what kinds of CSCL tools exist out there, and we will present the concept of affordance of a tool. Afterwards, we will approach the relationship of tools and enactment by analyzing one concrete CSCL tool (the GroupScribbles application [SRI08]) from the standpoint of the concepts and frameworks presented in chapter 2. We hope that this analysis, alongside the empyrical data about the usage of GroupScribbles gathered in the field (see chapter 4), will provide a first step in our understanding of how the design of the tool can support or hamper the enactment of CSCL activities.

3.1   Computer-supported collaborative learning tools

One of the most often cited theoretical underpinnings of CSCL is Activity Theory. *Activity theory* [EMPG99] is a meta-theory rooted in the cultural-historical writings of Vygotsky and his colleagues [Vyg78], and basically proposes a model of artifact-mediated and object-oriented action. In this model, the relationship between human subjects and objects in the environment is mediated by cultural means, such as tools and signs. Thus, in this conception, *tools mediate in human activities*, and are modified by those

activities, *reflecting* in its structural properties (shape, material, etc) the knowledge and experience about *how the tool should be used*. This definition of tool is very broad, and in fact it encompasses tools as disparate as language itself, a digital whiteboard or a wiki.

Thus, in any learning *environment* (such as our computer-integrated classroom, or even in a virtual learning environment designed for distance education), teachers and students will find a number of *tools* that can be used to mediate in *knowledge transmission* (if we adhere to objectivist views of learning) and *knowledge construction* (if we prefer constructivist theories of learning). This also holds true for CSCL systems and environments.

In literature we can find a number of attempts at summarizing and *categorizing* the vast number of systems and tools that have appeared in the field of CSCL since its arisal in the early nineties. We will include some of the most relevant here, in order to give the reader an idea of the nature (and the variety) of these tools.

Dillenbourg and Hong asserted that "many non-exclusive approaches exist by means of which a CSCL environment can directly or indirectly shape group interactions" [DH08]:

1. By designing a communication tool, e.g. a semi-structured interface that proposes *predefined speech acts*, in the form of buttons or sentence openers (see [BL96, VTJ99, Sol01], as cited in [DH08]).

2. By shaping (graphical) *representations of a task and the objects* to be manipulated by students, as in [Ros90] or [Sut99] (as cited in [DH08]).

3. By *forming groups* in a specific way ([Was98] or [WP01], as cited in [DH08]).

4. By providing team members with a *representation of their interactions*, in order to promote regulation at the group level (see [Dil02] or [JD08], as cited in [DH08]).

5. By providing feedback on the *quality of group interactions*, as in [MA95] or [CGS00] (as cited in [DH08])

6. By *scripting* the collaboration process using specific phases, roles and activities (see [HLVFAP$^+$06] or [DJ07]).

Other classifications are also possible. For example, Soller et al. [SMMJM05] focus on the *kind of feedback* about the interactions that is provided by the system. Thus, we could have the following kinds of CSCL systems:

1. *Mirroring tools* are those which collect data about the students' interactions and reflect this information back to the user (be it either to the teacher or to the students themselves). In this case, it is left to

human actors to compare this data with the desired state and to take any corrective measures. Examples of this kind of systems include [ADK03] or [BBD$^+$99] (as cited in [SMMJM05]).

2. *Meta-cognitive tools* are those that display information about how the desired interaction might look like, alongside any indicators on the current state of the interactions. Thus, again human actors are responsible for any diagnosis and remedial actions. [GGPFL04] and [Sim99] (as cited in [SMMJM05]) are examples of meta-cognitive tools.

3. Finally, *guiding systems* not only collect data about the interactions but also propose (and, in some cases, even execute automatically) any remedial actions to moderate the group's interaction, as found in [VTT$^+$04] or [AY98] (as cited in [SMMJM05]).

As the reader might begin to acknowledge, there is an enormous variety of CSCL tools following very different approaches, in part due to the fact that there is also a wide variety of pedagogical theories to draw from when designing tools. In fact, we could also make other classifications, less research-centric and more akin to the point of view of practitioners. For example, we could classify tools attending to the *phase* in the educational process where they are to be used:

1. *Authoring tools* are those that help in the design of collaborative activities, such as, for example, the Collage tool [HLVFAP$^+$06].

2. *Enactment tools* are those that are used during the execution of the activities, helping in the coordination or in the integration of the tools needed during the activity. In this category we could find collaborative scripting engines that "execute" sequences of educational tasks, such as CopperCore [MVRK09] or Gridcole [BLGSVG$^+$08] and many other VLEs. Also, the tools that are integrated in them (from text editors to chat utilities), and which are used by students to complete the activities, may also be categorized as enactment tools.

3. *Evaluation/assessment tools* are those that help teachers or professional evaluators in the self-reflection or evaluation of collaborative activities (see [JAS09b] for an example of such a tool).

Logically, our main interest lies in the second of these last categories, even if we should not neglect the influence that design or evaluation (and the tools used in those phases) could have in the enactment of activities. An interesting classification of *enactment tools* has been done by Vega in [VGBLGS$^+$08]. Even if the aim of this classification is very different from ours (to elaborate an ontology of service-based CSCL tools), its level of

abstraction (which does not preclude non-service-based tools) and teacher-centric point of view is most suitable for our needs. Drawing from classic CSCL literature such as [Kos96], a CSCL tool could be classified according to the *use* that teachers and students will make of them (i.e. the tasks that can be performed with the tool):

- A *perception* task, which includes reading or hearing of messages, documents, audio, video, etc.

- A *construction* task includes message construction, as well as other kinds of editing (e.g. text writing, drawing or modeling).

- A *communication* task, which can be synchronous or asynchronous, consists of exchanging messages of different types (text, graphics,audio, video or documents).

- An *information management* task can be specialized to publishing, retrieving, searching, sending or deleting some artifact (e.g. a document).

- A *computation* task, such as compilation or computer simulation.

It is important to note that in this classification not only CSCL tools are included (i.e. tools specifically designed with the shaping of collaboration in mind), but also other, more general tools can be found (e.g. text editors, document repositories, etc). This is done because a CSCL activity normally also includes non-collaborative tasks (e.g. individual work, such as reading a paper or writing a report) at some point of the activity [DJF09].

3.2 Affordances and tools

At this point, it may be interesting to look at the concept of *affordances* of a tool. The term affordance originated in the area of psychology, as the potential behaviors available to an animal in a given situation or environment [Gib86]. The concept of affordance, however, has been popularized in the human-computer interaction (HCI) field, in a slightly modified way, meaning the *potential actions that a user can enact* (or the actions that the user *perceives* as possible) *with a certain tool, in a certain context* [Nor02]. In fact, Norman distinguishes between *perceived affordances* (the actions that the user perceives as possible, very important from the usability point of view) and real affordances (the actions that are really possible with the tool, related to the tool's utility).

In education, the term affordances is used very often with an analogous, yet different, meaning. Kirschner et al. [KSKB04] distinguish between three kinds of affordances (i.e. opportunities for action) when analyzing and designing a collaborative learning environment:

- *Technological* affordances are akin to Norman's concept of affordance [Nor02], linked to the usability of the tool.

- *Social* affordances are "properties of the CSCL environment that act as social-contextual facilitators relevant for the learner's social interaction" [KKJ02], that is, that encourage the participants to communicate with one another.

- *Educational* affordances are those characteristics of an artifact that determine if (and how) a particular learning behavior can be enacted within a given context.

Affordances can be very powerful mediators in our analysis of the multiple tools in a classroom, since they can be seen as a link between the tools and the different educational goals of the teacher, which could be used to help teachers in orchestrating different tools in enactment. These links could be uncovered by an *affordance analysis* of the tools [Bow08]. This kind of analysis is used in Computer Science to find out what an item or program inherently facilitates (or makes more difficult) by the nature of its structure[1]. Moreover, this analysis could be potentially used not only for technological affordances, but also for social and educational affordances.

3.3 Exploring the role of tools in CSCL enactment

As we have seen, there exists a myriad of different CSCL tools which might be used in the enactment of activities (both collaborative and for individual tasks). Analyzing *how* each of them *affects teacher enactment* would be a huge undertaking; if we also notice that these tools can often be combined in the different tasks of an activity, the objects of analysis would become almost infinite.

A more pragmatic approach would be to analyze selected examples of CSCL tools, comparing them with the conceptual frameworks of enactment that we have described in chapter 2, but also by observing real classroom enactments using that tool (see chapter 4). By conducting this analysis, we hope to reap at least two benefits:

- By analyzing the tool from the standpoint of our teacher models, the models for appropriation of technology and the phenomena of flexibility and orchestration of CSCL, we may find out which of these aspects the tool excels in. Then, by finding which parts of the application

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[1]For example, when comparing the use of pen and paper for note-taking to using a laptop, one might note that pen and paper are cheap, easy to use to draw pictures and diagrams, and that the information needs to be rewritten in order to be copied, etc. On the other hand, a laptop is quick to type, easy to read the typed results, hard to use to draw pictures, digital data is easy to transfer and edit, etc.

design provide this excellence, we could propose recommendations to *guide the design of enactment tools*, exploiting these tool design aspects.

- This kind of analysis could also be helpful in the *flexible orchestration* of tools, if we manage to relate the tool (or, more concretely, the tool's affordances and uses) to the educational goals of teachers. This kind of mapping could be transformed into "improvisational orchestration patterns" that could be both used for the training of teachers as well as an element in the design of enactment tools.

In the following section, such an analysis is performed on *GroupScribbles* [SRI08], a simple CSCL tool for collaborative improvement of ideas. We have selected this application as an example worthy of study because of its *flexibility* and the potential it has showed in previous studies in supporting *teacher improvisation* [RTC+07, DAPHL+07]. Moreover, its *simplicity* makes it suitable to be introduced in real contexts, to be used by teachers and students without extensive technical training.

In our analysis we will follow this procedure:

1. Provide a brief *description of the tool*, including its main features and comparing it with the different CSCL tool classifications depicted at the beginning of this chapter.

2. Perform an *affordance analysis* [Nor02, Bow08] of the tool (see section 3.2). While affordance analysis is not an exhaustive method of analysis, it can help to inform design, uncovering advantages or major problems with a design.

3. Compare the tool with the *teacher model concepts* depicted in section 2.1, in order to uncover how teacher's intrinsic factors (and, specially, the educational goals) could affect the usage that teachers make of the tool.

4. Analyze the tool, comparing it with the different *models of technology integration* described in section 2.2, specially with the barriers model and the ecological model of the classroom.

5. Analyze the tool from the standpoint of *orchestration and flexibility*, as they appear in section 2.3. Special emphasis has been made in comparing this tool with the approaches described there, and in the search for potential "improvisational orchestration" patterns.

Given the depth of this kind of analysis, and due to time and space constrains, this documents contains the analysis of one tool. Further analyses should be conducted in the future to uncover further tool design guidelines such as the ones presented here.

3.4   The case of GroupScribbles

3.4.1   GroupScribbles

GroupScribbles (GS) software [SRI08] was originally designed and developed by SRI International, with the aim of enabling collaborative improvement of ideas based upon individual effort and social sharing of notes in graphical and textual form ("scribbles") [SP06]. GroupScribbles is designed to be lightweight, flexible, content independent and easy-to-adapt by teachers. It attempts to maximize the power of ink, improvisation, and interactive engagement, so that teachers can improvise different patterns of collaborative activities for students without the need for additional software programming. The whole idea of the application revolves around the metaphor of sticky notes and public/private whiteboards [DTK06], and it is specially suited to be used with tablet PCs or other input devices that allow for easy and expressive drawing [RTC+07].

Figure 3.1 shows the basic user interface of GS. In a GroupScribbles activity, usually the lower part of the screen is the user's *private dashboard*, where the user's scribbles are created and drawn onto. On top of the private board, the main area of the screen is normally occupied by one or more *public boards*, which everybody can see and modify (by dragging scribbles in and out of the board, by rearranging them or by drawing directly on the board). Finally, the topmost part of the interface hosts a (surprisingly low) number of *tools*, allowing users to draw, input text and draw stamp forms of different colors and sizes. Moreover, teachers have an additional number of "teacher options" available, which allow them to enforce certain aspects of the tool (like the writability of boards, or showing/hiding the scribbles in a public board board).

If we compare the GroupScribbles application with the classifications of CSCL tools presented at the beginning of this chapter, we find that:

- GS could be said to provide a *graphical representation of the task* and objects to be manipulated by students (in this case, through the metaphor of sticky notes); other features like specific group formation or scripting could be implemented in GS through external means (e.g. social interaction, if the teacher states that certain students should interact in a separate board), but they are *not* enforced by the tool.

- Regarding Soller et al.'s classification, GS could be said to be the simplest kind of *mirroring tool*, since it reflects the actions of any user back to the other users, in a straightforward way.

- A peculiar characteristic of the GroupScribbles tool is that it could be said to be at the same time an *authoring tool* and an *enactment tool*; in fact, there is no real difference in designing an activity with GS and enacting it. This is a really interesting feature, since it allows for easy
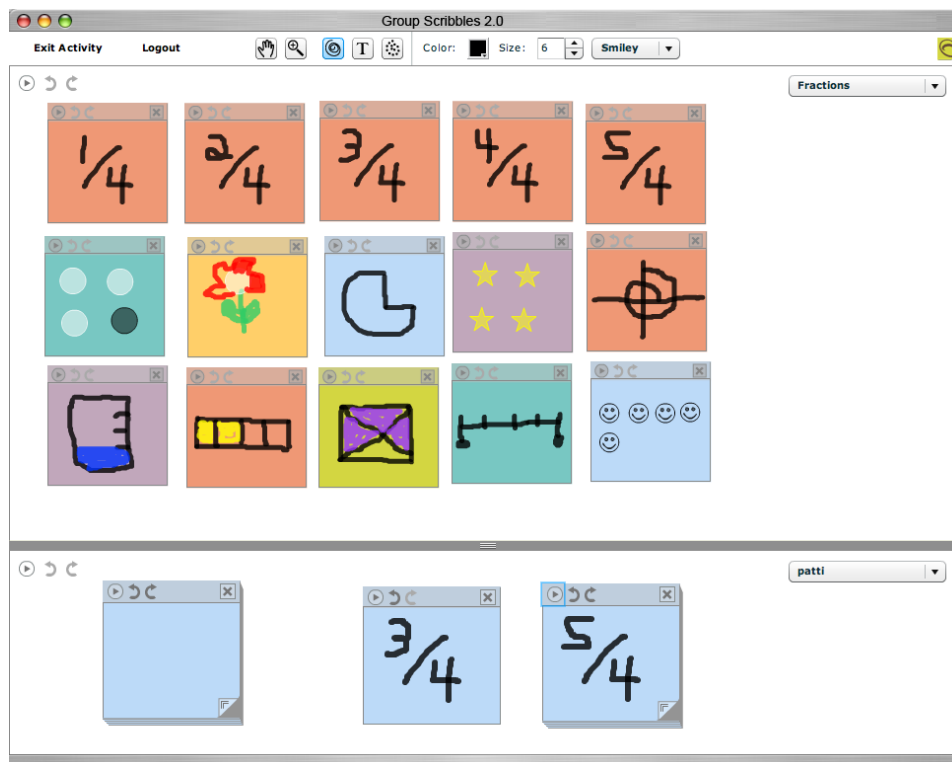
Figure 3.1: User interface of the GroupScribbles collaborative tool

redesigning of activities during the enactment, an important requisite for allowing improvisation in teacher enactment, as we saw in section 2.3.

- Finally, the kinds of tasks that the tool can perform include *perception* tasks (showing images as board backgrounds, and the scribbles themselves), *construction* tasks (since scribbles can be constructed, and diagrams and arrangements of scribbles can be done in GS) and, also, a limited kind of *communication* tasks (communicating through scribbles), although this is not the main goal of the application.

These classifications begin to give an idea of what kind of CSCL tool we are facing, and hint at what kinds of interactions and educational goals could be achieved through it. Deeper understanding, however, will be gained in the following analyses.

3.4.2 Affordance analysis

After performing an affordance analysis of the GroupScribbles tool, drawing from the work on affordances for electronic learning environments described

in [KSKB04] and [Bow08], and combining it with the work with GS by other authors [DTK06, DAPHL$^+$07], we can draw the following list of affordances (what is specially easy, given the tool's design and structure) and anti-affordances (what is specially difficult or just impossible):

Affordances

- Easy visibility*

- Lots of space*

- Simple to use

- Immediate feedback

- Easy to share scribbles

- Easy to draw expressively*

- Easy to zoom/pan

- Easy to type text*

- Easy to undo/redo (history)

- Easy to create (many) new scribbles

- Easy to create (many) new boards

- Allows background image

- Easy to copy/clone scribbles

- Easy to rearrange scribbles

- Easy to modify others' scribbles

- Easy to change scribbles' color

- Activities can be reached from anywhere* (provided the server is accessible)

- Easy to access (no installation required, just a Flash-enabled web browser)

- Allows anonymity (the author of a scribble is normally unknown)

Anti-affordances

- Cannot work without several networked computers

- Cannot work without an installed server

- Cannot include more than one image

- Cannot draw lines/polygons

- Information is not machine-interpretable

- Cannot export/interchange activities

- Cannot prevent users to modify each other's scribbles

- Cannot move drawings (either inside and scribble or on the board)

- Cannot change or edit drawings (only delete the drawing)

- Cannot enter extensive/large ideas (scribbles are small)

- Cannot change scribbles' size or shape

- Does not include educational materials

- Does not include predefined structures of boards

- Does not provide accountability by default (scribble authors are unknown)

The reader may have noticed that some of these affordances are marked with an asterisk (*). These indicate *conditional affordances*, which are potentially supported by the application, but which require an external element to be exploited (such as a digital whiteboard for the "easy visibility" affordance, or a tablet PC for the "expressive drawing" affordance). This fact is very interesting, since it has to do with the *orchestration of tools* that we exposed in section 2.3, and it indicates that certain *combinations of tools* can be specially suitable if we want to achieve a certain educational goal in an activity (e.g. liberating the creative drawing potential of students in an activity would require GS *and* a tablet PC, and would probably not be achieved if one of them is absent).

Moreover, the affordances presented so far could be termed technological affordances [KSKB04], since they are expressed in terms of direct actions that can (or cannot) be performed with the tool. Yet, if we think about how a teacher can enact a CSCL activity with GS (forming groups, sequencing different tasks in different boards), some of these affordances acquire a new meaning, and thus we would obtain a list of higher-order (or educational) affordances:

Educational affordances

- Since scribbles can be created and edited by anyone, GS seems to be specially useful for the collaborative construction, improvement and arrangement of (simple) ideas.

- Since boards are used to perform tasks, it is easy for teachers to add new tasks in real-time (by creating and editing new boards), thus *changing the flow of the activity*.

- Since boards are visible by anyone (including the teacher), and feedback is (almost) instantaneous, teachers can *assess immediately the progress* of the activity.

- Since boards can also be used to perform different tasks in parallel by different (socially-mediated) groups, teachers can *change the formation of groups* in an activity in real time.

Educational anti-affordances

- The space constraints of the interface and the scribbles themselves make GS less suitable for activities that require extensive usage of text artifacts (e.g. long written reports).

- The limited enforcement features of GS (e.g. visibility of scribbles, read/write permissions on different scribbles, the fact that anyone can manipulate anyone's scribbles) disallow most machine-driven *shaping of the interaction* among students.

3.4.3   Teacher model analysis

Given that in section 2.1 we proposed that the decisions that shaped teacher enactment depended on a number of factors (most of them intrinsic to the teacher, such as the knowledge, goals, beliefs or emotional attitudes, but also on the context of the teacher), we will now take a look at how the design of GroupScribbles could interact with those factors. We are aware that these factors will vary greatly from teacher to teacher, but we will try here to anticipate probable effects, drawing from the work of Chen and Looi [CL08a, CLed] (who analyse several teacher enactments with GS using the Teacher Model Group's teacher model) as well as from our own experience with the tool:

- Since GroupScribbles is a CSCL tool, a minimum amount of *technical knowledge* is required from teachers (although its simplicity make this requirement much lower than with other CSCL systems). Also, basic *knowledge about collaborative learning* practices would be needed, if a

true CSCL activity is to be enacted. Moreover, due to the unstructured and freeform nature of the GS tool, which require from teachers to develop their own activities, a good amount of *content knowledge and pedagogic content knowledge* would be required by any prospective teacher trying to leverage the affordances of GroupScribbles.

- Regarding teachers' *goals*, having overarching goals regarding the fostering of collaboration among students would be the main requisite for teachers using GroupScribbles. Other, more concrete goals of the activity can make GS a suitable choice (or not): requiring multiple representations of a concept, refinement of simple ideas, arrangement and classification of elements, etc.

- Several *beliefs* could be very useful for teachers trying to enact CSCL lessons with GS: first of all, beliefs in the benefits of constructivist and collaborative learning approaches would be one of the main requirements; also, beliefs about the benefits of ICT in education would be very useful, specially in order to overcome the occasional glitches that GS technology (or other artifacts in the classroom) might present; GroupScribbles' ability for multiple representations of the same idea would be most exploited by teachers holding beliefs about the different learning styles of students.

- Regarding the *emotional* aspects of GS usage, obviously an aversion to technology (which more than a few teachers show) would be a great obstacle to the integration of GS in any classroom. On the contrary, a positive attitude towards continuous learning and the creativity of teaching would greatly help teachers in finding novel uses for the tool and inventing original activities that engage students in collaborative learning.

- Finally, teachers trying to make effective use of GroupScribbles should be immersed in a *favorable context*, to reap all the tool's benefits. Thus, adequate tools (preferably, tablet PCs and/or digital whiteboards) should be available in the classroom, the schooling system and the school culture should allow for the implementation of the teacher's own materials, etc.

As we can see, there exists a large number of factors that might affect how a teacher enacts activities with GroupScribbles. Even if the requirements are not overwhelming, several of them are not exactly commonplace in many Spanish schools, and thus it would not be advisable to integrate this tool into *every* school in the country. Teachers (or principals) should use their best judgement to decide.

3.4.4   Technology integration analysis

We will now take a look at the GroupScribbles tool in light of the concepts exposed in section 2.2:

First- and second- order barriers.   Ertmer's model of the barriers for adoption of technology [Ert99] refer to the teachers' intrinsic factors as well as to their context. Thus, the effects of these barriers in the adoption of GroupScribbles should be judged in a case-by-case basis. We can, however, try to predict which are the best conditions for the integration of the tool.

Regarding *first-order barriers* (external to the teacher), the most obvious requirements for the integration of GS would be to have adequate infrastructure for its usage (reliable servers, tablet PCs, digital whiteboards) in the classroom; yet, we should not forget about other external factors like an adequate schedule that allows teachers to dedicate time to the design of activities, or adequate training in collaborative learning concepts and in the usage of ICT.

Second-order barriers can be more difficult to detect and to overcome, since they involve non-measurable aspects like beliefs and values. Positive beliefs about technology and about the benefits of collaboration in education are the two main requirements in this regard (as with any other CSCL tool). The willingness and ability to create their own material (i.e. creativity) is probably the other main requisite that a teacher should comply with, in order to leverage the power of GroupScribbles.

Ecological perspective.   As it occurred with the barriers model, a more detailed analysis, taking into account the concrete properties of each classroom ecosystem (see section 2.2), would be needed. What we can do is analyze the *qualities* of the "invading species" (in our case, using GroupScribbles to enact CSCL activities) and try to anticipate probable interactions with a computer-integrated classroom ecosystem.

Regarding the *qualities* of GroupScribbles use as a species, we can assert that it may have a *high longevity* (provided that it is compatible with the existing ecosystem in the first place), since its simplicity makes the use sustainable even in the absence of researchers. This simplicity also plays in favor of its *high fecundity*, as teachers can easily train one another, thus spreading GroupScribbles use. The free, unstructured nature of the tool makes it *highly mutable*, at least potentially (the modifications of its use really depend more on the teachers than on the tool itself).

The *interactions* of the "use GroupScribbles" species are much more complex to predict. We can, however, anticipate that classroom ecosystems where *tablet PCs and digital whiteboards are present* would be much more suitable to the survival of this species. Even more important than the presence of the hardware is the fact that the hardware *is used often*, and that

its *benefits* are perceived by the keystone species: the teacher.

3.4.5 Orchestration and flexibility analysis

The potentialities of GroupScribbles for improvisation have been already referred to in literature [DAPHL$^+$07] and, in fact, improvisation was one of the main concerns that drove the creation of the tool, intended as "a platform that supports teachers in inventing and enacting new forms of collaboration and coordination in their classroom without resorting to additional programming." [RTC$^+$07].

Thus, GroupScribbles functions in many ways as a "blank slate", with very lightweight structure, intended to be complemented by face-to-face interaction (i.e. socially-mediated interaction rather than technology-mediated interaction [DAPHL$^+$07]). In this sense, GS is *highly flexible* by design, due to its leverage of the social coordination methods, which we are used to improvise with.

Regarding more concrete flexibility features, and as it was hinted in the affordance analysis above, GroupScribbles allows for flexibility in *group formation* (since it is largely socially-mediated) and in the *creation of new tasks* (e.g. by creating new boards) or *modifying the flow of activities* (which also is socially-mediated). Also, *contingency* could be easily implemented (e.g. by the creation of additional boards to be used "just in case"). It is also worth noting that, due to the immediate feedback that GS provides on the activities of students, the implementation of contingency based on real-time assessment (in a similar way to the scheme described in [VFHLAP$^+$09]) would be quite easy.

An interesting idea in the design of GroupScribbles is the notion that there exists no difference (technologically speaking) between designing an activity and enacting it, which links with the idea of *improvisation as real-time composition* presented in section 2.3. However, for this feature to help in improvisation, it is required that this activity (design/enactment) can be made *easily and rapidly* with the tool. GroupScribbles achieves this by recurring to a well-known metaphor (i.e. stickers and whiteboard), and by restricting the number of options and tools available for the design/enactment of the activity to just a few, in order to reduce the user's cognitive load. This feature of GS hints at a possible pattern to guide the design of flexible/improvisational CSCL tools: *lightweight design* (or at least, the ability for fast and easy re-design of activities).

Regarding the use of CSCL scripts with GS, nothing precludes the teacher to enact a script using this tool (in the same way that nothing precludes a teacher from enacting a script using pen and paper). However, the *support* that GS provides to lighten the load of orchestration from the teacher, is *very thin*. Basically, it provides a few features that may help in self-regulation (the fact that only one person can move a scribble at the same

time, teacher controls for boards) or in the assignment of tasks (by using separate boards for different tasks and groups). There have been, however, efforts towards helping teachers structure the activities through script-like mechanisms [NSGL07].

Thus, we can conclude that GroupScribbles does not provide much help in orchestration, except by providing very simple but flexible metaphors that can restrict somehow the available options for interaction. In fact, *demands on the teacher are high* in all phases of the activity: the teacher has to design from scratch the activity flow, improvise, supervise, react, and evaluate based on "ephemeral data". This fact has important implications on the *required expertise of teachers*, since this kind of mental load can be too high for a novel teacher. Also, since improvisation requires a number of internalized patterns, novel teachers will have a much harder time improvising (with GS or otherwise), due to the lack of these internalized patterns. Yet, this idea opens a new path for future studies that could try to uncover these patterns and expose teachers to them. These studies should also consider how each of these patterns should be enacted, depending on the tool that is used for the enactment.

3.5 Summary and... what is missing?

This chapter has delved into the concept of tools, affordances, concentrating specially on CSCL tools. We have analyzed the affordances and main features of one tool, GroupScribbles, with regard to the concepts of enactment that had been exposed so far. This exemplary analysis has already uncovered a number of interesting concepts and ideas:

- GroupScribbles provides a number of concrete educational affordances that make it specially suitable for certain kinds of educational goals and activities (e.g. construction/rearrangement of ideas, brainstorming, activities that require anonymity of participants, etc). Such *mappings of educational goals and tool affordances* could provide a first step in helping teachers orchestrate the different tools that they have available in the computer-integrated classroom. Also, the conditional nature of some of the tool's affordances also hints at the usefulness of *combination patterns* of tools that can also be useful in the election of tools to be used in a CSCL activity.

- GroupScribbles is a highly *flexible* application, and thus it is specially suited to situations in which *contingency* plays an important role in teachers' plans, or when *unexpected inputs* are encouraged. GroupScribbles can also be very useful when teachers want *immediate feedback* about the students' progress on the activity.

- However, the flexibility of GS is counterweighted with the small amount of help that is provided in the *orchestration* of the activity. Thus, GS would not be suited to *very complex* CSCL activities with too many students and/or intrincate group formations, or any situation where socially-mediated coordination is not adequate. It would be interesting to study whether this high-flexibility, low-orchestration feature is a design tension [Tat07], or both factors can be somehow optimized.

- The fact that, in GroupScribbles, *design and enactment* of activities comprise basically the *same actions*, which can be performed easily and in real-time, hint at a useful pattern for the design of CSCL tools that support flexibility and improvisation.

- The analysis performed also indicated that the concrete context and the *teachers' intrinsic factors* can be determinant in the success of its integration in the classroom, even if GroupScribbles presents generally good potential for "ecological integration". This is specially true for the *expertise of teachers* using GroupScribbles, since an effective usage of the tool seems to require a creative, knowledgeable and reasonably expert teacher.

However, if we go back to the concrete educational setting in which we are focusing our study (a computer-integrated classroom), we might notice that it is full of tools that can be used by teachers and students in the enactment of CSCL activities. Thus, the analysis of just one software tool, as interesting as it may be, can look clearly insufficient; subsequent analyses of other CSCL tools can provide further insights into the design of enactment tools. Furthermore, even if in this section we have concentrated (as most CSCL literature does) in the capabilities of software, *we should not ignore the affordances of hardware* and, specially, certain combinations of hardware and software (what we could call *combined affordances*). Just as certain GroupScribbles affordances could only be exploited by the use of a digital whiteboard, more attention should be paid to how CSCL software and hardware can be combined to provid synergistic scaffolding [Tab04]. Moreover, neither should we ignore the usability and emotional sides of the technologies we are using in our educational contexts: even the best CSCL software, enacted by an expert teacher, can be rendered ineffective by poorly designed or poorly maintained hardware.

Chapter 4

Fieldwork: Six months at a primary school

With a buzzing sound, the door opened. The researchers crossed the playground, now empty, and walked towards the most modern building of the school, which served as the visitors' entrance. Once inside, their senses were assaulted by posters, signs, and other children-made projects, which covered every inch of the school's walls. After greeting the school's warden, the three strangers walked up to the door of the principal's office which, as always, remained open. They knocked the door gently, and a "Yes?" came from the farther end of the room. When their three heads finally peeked inside, the principal had already got up, smiling, in order to greet the newcomers.

The walls of the office were as crowded with paperware as the rest of the school: posters, timetables, more posters, reminders, children's drawings... only the large window to the playground which was at the end of the room offered some rest. For about an hour, the principal and the researchers talked about the topic that had brought them to Cigales: the use of new technologies in school. They talked about the uncommon amount of technology that the school had, how it had been obtained, the government policies about it... they talked most about the plans of the researchers: to observe the everyday usage of technology in authentic settings, by introducing a new software in the classrooms and seeing how teachers and students reacted to it. But the most important thing they discussed was how they were going to do that with minimum disturbance of the already overcrowded school timetable, and in a way that was aligned with the curriculum. Finally, they agreed to give a short presentation about the software and the research to the teachers, that very same afternoon.

Shortly afterwards, the researchers met the principal and some of the school's teachers in order to have lunch in one of the village's restaurants, where many of the school's staff used to have the lunch break when there was afternoon work to be done. The food was plain and looked homemade, and the atmosphere was cheerful, with the teachers (almost all of them women) making jokes and commenting the day's most interesting pranks and gossip. All in all, it was an unorthodox, but certainly Mediterranean way of introduction to a research context...

The above vignette describes the first introduction of a research team from the GSIC-EMIC group at the University of Valladolid, to the educational setting of a primary school located in Cigales, a village nearby Valladolid, in Spain. This exploratory intervention, however, was not an isolated effort towards studying the enactment of CSCL activities, but rather it was part of a series of studies that the group has been conducting over the last three years.

As it was stated in the opening chapter of this document, one of the research interests of the GSIC-EMIC group is to support practitioners of CSCL in all the phases of their practice (design, enactment and evaluation). More concretely, one of the research lines of the group tries to explore the *tension between script/structure and improvisation/flexibility*. Along this line, a series of studies have been performed at the GSIC-EMIC in order to explore this tension, mostly using the GroupScribbles (GS) [SRI08] software. In these studies, a number of limited experiences were conducted, both in university settings and in primary schools. In these first studies, GS was found to *allow for improvisational teaching and flexibility* in the face of emergent situations, at the cost of putting *high creativity and knowledge demands* on teachers [DAPHL⁺07].

However, these limited experiences only provided preliminary evidence about the nature of improvisation with CSCL technologies such as GS, and the plans for a more *in-depth study* began to take form. The following sections contain some of the main findings of a more extensive field study in this line, conducted during *six months* in the *authentic setting* of a primary school, located in Cigales (Spain). In this chapter we will pay special attention to the matters of teacher enactment presented so far in previous chapters (e.g. improvisation, flexibility and orchestration), and to the effects that the introduction of a new software (GroupScribbles) had on this concrete educational context. Please refer to [VP09] for a more detailed description (in Spanish) of the study and its results.

However, it should be noted that this field study is not the result of the sole effort of the author, and that *the focus and goals* of the study are *not identical* to the goals of this document (even if they overlap for the most part). In fact, at the beginning of the study, the goals of the study were

expressed using the following research questions:

- *"How does GS affect these teachers when they design and enact activities?"*

- *"Can we draw any conclusions from this understanding that inform us in the design of CSCL tools?"*

As we can see, the goals are very similar, and the ultimate goal (to guide the design of CSCL tools) is the same as the one stated in chapter 1. Yet, in these questions there is a narrower focus in GroupScribbles as the selected tool for the study, and a wider focus in both the design and enactment of activities (note that we are not specifically talking about CSCL activities). Despite these differences, we think that this study collected very valuable data, not only about the *context and intrinsic qualities of the school teachers* (which, as we have seen, is of utmost importance at various levels in the kind of research that we are proposing), but also about the peculiarities of *teacher practice in designing and enacting activities* in real[1] computer-integrated classrooms.

Most of the fieldwork and later analysis of this study was conducted by *two PhD students* (supported by several more experienced researchers, both from the pedagogy and computer science sides): a pedagogist who tries to understand how technology can help or hamper the creative teaching processes of teachers, and a telecommunications engineer (yours truly), who intends to design and implement technologies that help teachers in the enactment of classes. Thus, this humble author cannot claim exclusive authorship of the following findings, although he does claim responsibility on any errors that could be found in this description of them.

This way of working, in a small, multidisciplinary team working closely and sharing the same tasks of the field work, brings about several *advantages*, such as providing different points of view and analyses for the same phenomena, or the opportunity to gain experience about different aspects of CSCL research. We believe that these advantages greatly outweigh the difficulties that arise from the usage of different languages and conventions, or the decrease in efficiency when compared with a more specialized/segregated way of working. In fact, this document reflects in part these advantages and disadvantages, being far more oriented towards pedagogy than the average work of a technologist.

The rest of the chapter is organized as follows: first, the field study *goals and methodologies* are described; afterwards, we summarize the main *results* of the study, grouped around the four main categories of interest of the study (context, beliefs and values, background and training, and design and enactment); and finally, the results are *discussed* and related to each other and with existing literature, in an effort to explain the events observed.

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[1]As opposed to laboratories or other controlled learning environments.

4.1 The research: Design and methodologies

4.1.1 The field study: Six months studying enactment in Cigales

In design-based research literature, it is acknowledged that the research can be preceded by one or more *pilot studies* to take place in the same authentic contexts that are going to be modified later on [CCd$^+$]. This is done not only to understand the myriad of factors that the design-based interventions will have to face, but also to provide data for a first round of theorization and design, in case there does not exist a widely accepted model on how and why the phenomena under study works in that kind of educational setting.

This was precisely our case: at the beginning of the 2008-2009 academic year, contacts had been made with the principal of the "Ana de Austria" rural school [C. 09] in Cigales (Spain). As we found out, the school, despite being publicly funded and being in a rural environment, was equipped with a considerable amount of technological resources, from digital whiteboards to tablet PCs. This, coupled with the enthusiasm of the school principal for the usage of new technologies in education, and the openness of the school to participating in research projects, made the GSIC-EMIC group think that it would be a good context to explore the design tensions between structure and improvisation. Thus, a set of experiences was agreed upon, and soon a small research team (including this humble author) began working at the school on a regular basis.

Methodologies

Many research studies begin with the statement of a problem or question. In order to solve that problem, very often the researcher uses one or more theories, and poses an hypothesis about what (and why) should be the solution to that question, which will later be proved or disproved by empyrical means. However, this is not always the case: there is also research that acts in the opposite direction, and which tries to construct theories first, drawing from empyrical data. This approach can be specially useful when there is a lack of well-defined theories about the phenomena under study [GS67].

This was the case of our exploratory work at the Cigales school, since there was not a well-accepted theory on how teachers improvise and orchestrate with CSCL tools in a computer-integrated classroom. Thus, we adopted such an approach, drawing several principles and methods from a established methodology in that vein: *grounded theory.*

Grounded theory [GS67] is a research methodology which was first put forward in the sixties, in the area of social sciences. In brief, grounded theories are developed directly from the data during research, as opposed to grand theories (or logical-deductive theories), which are developed first, and afterwards compared with empyrical data. In grounded theory, a variety of

data collection methods are the first step. From the data collected in this first step, the key points are marked with a series of codes, which are extracted from the data. The codes are grouped into similar concepts, in order to make them more workable. From these concepts categories are formed, which are the basis for the creation of a theory, or a reverse engineered hypothesis. That is the main goal of grounded theory, to find out what theory accounts for the research situation as it is. As this theory emerges, the researcher has to constantly compare new data (and also past literature on the subject) with it, modifying it where appropriate, so that the theory can explain all the available data.

Grounded theory, however, deals mostly with the analysis of the data, and it does not specify how the data should be collected, or what should be the design of the experiences or experiments of data collection. In fact, both qualitative and quantitative methods can be used to construct such theories [Yin94]. Thus, in order to design and implement this first study, we decided to adhere to the *case study methodology* [Sta95]. The election of this kind of qualitative methodology [DL05] was due to two reasons: it aims at describing a certain situation or phenomenon in a concrete context and in deep detail; and the group had considerable previous experience in case studies of different kinds [JA06, HL07].

Following the principles and terminology of case study research [Sta95], we can say that ours is an *instrumental case study* (as opposed to an intrinsic case study, since it serves a purpose out of itself, namely, to investigate the phenomenon of enactment and inform the design of CSCL environments). The definition of our case study followed several steps:

1. *Choice of the case and definition of its characteristics.* We chose the concrete case for our study and established its limits (the school of the CRA "Ana de Austria" in Cigales). Afterwards, we analyzed its characteristics and determined what would be the main function of the study (to analyze the phenomenon of "disciplined improvisation" of teachers when they design and enact activities with GroupScribbles).

2. *Definition of the framework of the case.* In our case, we would make special emphasis on three aspects, a) general characteristics of the school, b) the evolution and current situation of the technological resources of the school, and c) educative projects that support the school's teaching practice.

3. *Definition of the case's issues.* An essential aspect of any case study is the definition of the study's main topics, which will help us understand it in depth. In our case, we had defined two of them:

   - How does GroupScribbles affect teachers when they design and enact activities?

- Can we draw any conclusions that can inform the design of flexible CSCL tools?

4. *Proposal of research topics.* Once we had defined our issues, we had to determine how we would study them, through a series of specific themes. In our case, these topics were not selected previously, but rather they emerged from the data as it was analyzed. As we found out, the following themes emerged from the data:

   - The context and its constraints: which are the limitations that teachers face due to the concrete context of the case, such as its location, its teaching culture, organization, etc?

   - Beliefs and values: what do teachers think or believe about relevant topics such as education, the role of ICT in education, improvisation, or collaborative learning techniques?

   - Background and training: what training have the teachers received, both generally and specifically in ICT usage? what are their motivations, past experience and professional trajectory?

   - Design and enactment: what do teachers do in class, both with and without technology? what kind of activities do they design?

5. *Definition of additional informative questions.* Even the research topics are too abstract to guide the data gathering process. This is why they have to be made more concrete, by posing a number of informative questions that will illuminate each of the topics. These questions would guide us in the elaboration of the data gathering tools, such as interview scripts or observation sheets. Please refer to [VP09] (appendix A) for the complete list of informative questions, which was not included here for brevity's sake.

6. *Selection of mini-cases, data sources and techniques.* Once we knew what information we wanted to gather, we had to decide where and from whom it was going to be obtained. The roles of the researchers and the teachers were defined: In our case, we focused on 8 teachers from the school, 5 of them generalistic teachers (in K6-7 level), 2 specialists and also the principal of the school. All of them would be questioned and/or observed designing and enacting classes. Furthermore, the (very informative) school website [C. 09] would be searched for complementary documental information.

Figure 4.1 summarizes the outcome of this process of definition of the case study.
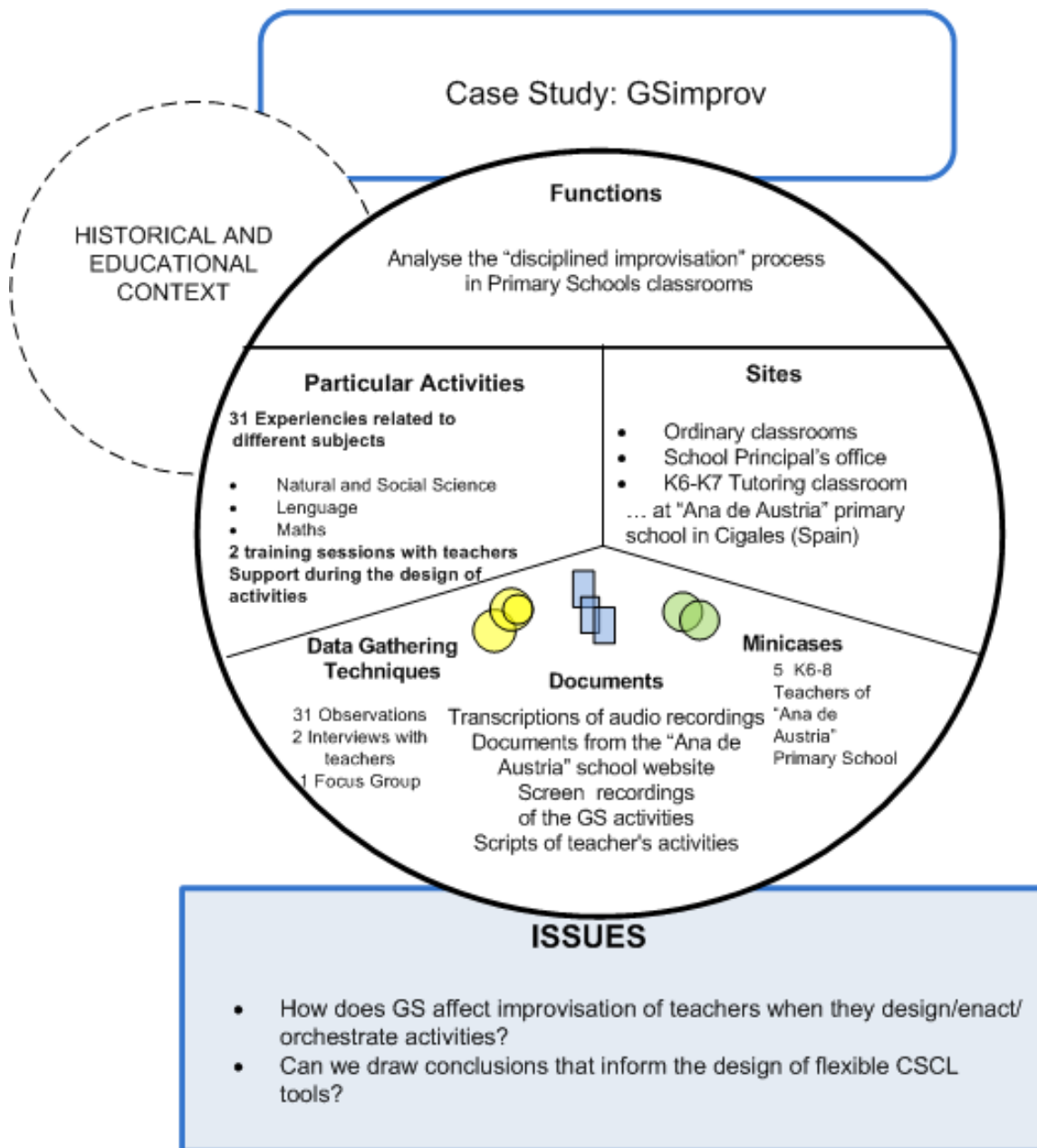
Figure 4.1: Definition of the CRA "Ana de Austria" case study

Data gathering sessions and techniques

In order to answer the informative questions, and to clarify the aforementioned research topics, we decided to use a variety of techniques, most of them very common in qualitative research and grounded theory. The *moments and nature of the data gatherings* were agreed upon in the first meet-

ings with the principal and with the teachers, and they took into account, not only the research interests presented so far, but also the interests of the school's teacher community. Thus, the following data gathering techniques and moments were defined:

- *Training sessions.* Two formal training sessions, of two hours each, were to be given to the participant teachers. The first one, at the beginning of the intervention, concentrated on the basic usage of the tool. The second one, halfway through the interventions, was more directed towards advanced uses of the tool and design of more complex activities with GroupScribbles. We decided to provide few training sessions in order to observe what kind of activities and uses of GS came to the teachers "naturally", instead of imposing them activity patterns of our own. These sessions were audio recorded, and the screen of the presenter was also recorded.

- *Activity design support.* A number of sessions of activity design took place, in which the researchers helped the teachers to transform their activity ideas into GroupScribbles activities. The need for this kind of sessions faded with time, as teachers progressively internalized what was (and was not) possible with the tool, and thus they evolved into brief informal conversations with the teachers, several days before the session was to be enacted.

- *Activity enactment support – Observations.* It was agreed with the principal and the teachers that GroupScribbles would be used in at least one session per week, by the 5 participant generalistic teachers. Researchers were to be present at those sessions, to provide technical support, but also to observe the enactments of teachers (thus, in these sessions the researchers used *participant observation* techniques [San90]). Most of the 31 sessions that took place were observed by two researchers, who took notes independently (for observer triangulation). The sessions were audio recorded, with additional data coming from screen recordings of the teacher's computer.

- *Focalized data gathering – Interviews and focus group.* In order to clarify many of the aspects related to the school context and teachers' perceptions on the topics of interest, three semi-structured interviews [Wen01] took place, with the principal and two of the generalistic teachers. Also, a focus group [Kru88] was held with the rest of the teachers (including specialist teachers). These sessions were audio recorded and later transcribed, and two researchers were present at them, one as interviewer/conductor, and the other as assistant and observer (i.e. taking notes).

- *Access to documental sources.* Finally, the researchers had access to the documents that informed about the resources, educational projects and activities of the school[2].

Figure 4.2 summarizes the different data gathering sessions that finally took place in the "Ana de Austria" school during the study.

Data analysis techniques

In a qualitative research inquiry such as the one described so far, the process of data analysis consists mainly in the interpretation, assignment of meanings and categorization of the data collected during the fieldwork. Specially important is the *triangulation* of data coming from different sources and techniques, in order to increase the credibility of the findings. The following analyses took place:

- The material from the *interviews and focus group* (see previous section) was analyzed using *qualitative analysis* techniques [Kru88, Dil04], in order to increase our knowledge of the context of the "Ana de Austria" school, and to get to know the teachers' background, knowledge, beliefs and values (which, as we have seen in chapter 2, are very important factors for the enactment of classes). In this analysis we had no predefined categories of analysis, but rather we let them emerge from the transcriptions themselves, as it is commonly done in grounded theory [GS67, SC90].

  More concretely, we took the transcriptions of the interviews and focus group, and followed a method of analysis similar to the synthetic analysis described in [Eav01]. In this method, we highlighted the ideas that appeared in the text (using a qualitative analysis software tool called NVivo [Ric99]). These ideas, or "open nodes" were later clustered into higher level concepts, until we reached a small number of *categories* of ideas that emerge from the text. Section 4.2 contains the main categorized ideas that emerged from this analysis, paying special attention to the ones that appeared more recurrently.

- The *designs of teachers' activities* with GroupScribbles were also analyzed. One of our main interests was to determine what kind of activities were fostered by the tool in a natural way (thus the scarcity of training about the tool or on what kind of activities *should* be designed). The creative process of designing an activity, however, is complex and not easily analyzed. We decided to draw information from multiple sources:

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[2]this documentation is, in fact, public and it is available from [C. 09].
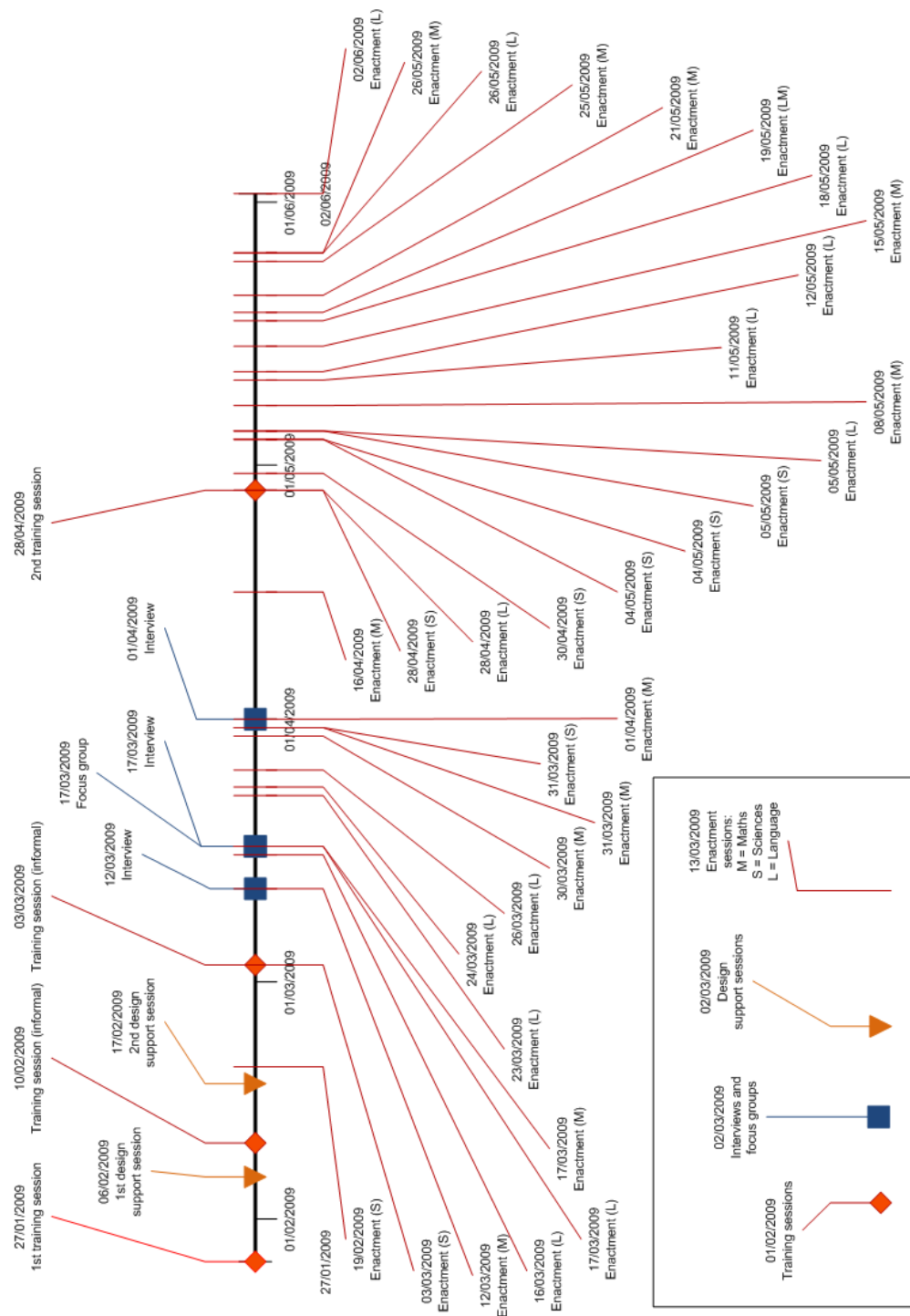
Figure 4.2: Timeline of the data gathering sessions performed in Cigales

- The field notes and audio recordings of the activity design sessions where researchers helped teachers in implementing the activities with GS.

- Informal conversations with teachers, either before or after the sessions, where teachers commented on the structure and goals of the activities.

- Several fragments of the teachers' own notebooks, used to prepare the activities, write down results, etc.

- The field notes and recordings of the observations of the enactment of sessions can also provide (indirect) information about how the activity was designed, specially regarding implicit aspects of the design (routines, internalized scripts) that never make it to the written plan of a class [Sch99].

Using these fragmentary sources, 30 activities were analyzed, looking for common design patterns, and observing the temporal evolution of the designs. These patterns were then compared with other patterns already found by the creators of the GroupScribbles tool in their Contingent Pedagogies project [Int08]. The results of this analysis are described in section 4.2.

- The aspect that we were most interested in was probably the *teachers' enactments of activites* with GroupScribbles. We were specially keen on seeing how those enactments differed from the original design of the activity, be it either due to students' feedback or other unexpected circumstances. The audio and screen recordings of the observed lessons, as well as the field notes taken by researchers, were analyzed. Two different analysis were performed:

  - Attending to the *coarse-grained temporal flow of the activities*, from the point of view of the different social planes involved (individual work, small group, whole class) as well as looking at the different tools used to enact each phase (tablets, blackboard, digital whiteboard, etc). The level of granularity in this case is very similar to that of a CSCL macro script (see chapter 2).

  - Attending to the temporal flow of the teacher's *discourse*, looking at the social levels in which the teacher was interacting, but also the media/tools used. This analysis tried to capture interruptions, small improvisations and other fine-grained enactment events.

These analyses were done manually for each of the enacted lessons, and later represented both *textually* (as a description of the sequence of phases) and *graphically* (in diagrams representing the flow of the
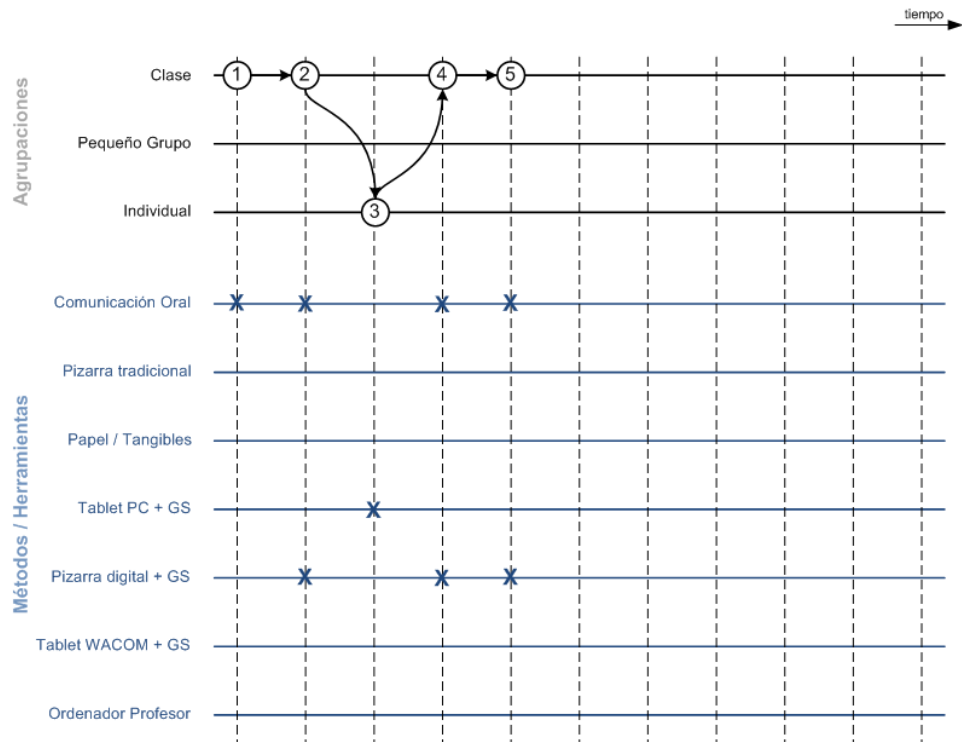
Figure 4.3: An example of the analysis of an activity enactment in Cigales

activity across social planes and tools, similar to the graphs used to represent script flows in [DH08] – see figure 4.3 for an example). The results from this analysis are summarized in section 4.2.4.

4.2 Results of the study

4.2.1 The context

The empty school corridors resonated with the sound of our footsteps and the faint explanations of a teacher somewhere else. Cautiously, we peeked inside of one of the K-6 classrooms. Standing in the middle of the room, the teacher was explaining something, probably related with today's activity. When we knocked on the door, the teacher smiled and let us in. "Just a moment", we answered, "we'll go fetch the cart". One of the students could not hold up any longer and bursted into a happy "Yay! today we have tablets!". A moment later, we came back with the cart that contained some twenty tablet PCs and a wireless access point. In a few minutes, the infrastructure would be ready...

Seventy-five minutes later, the teacher closed the activity, and let the children go to the playground, since it was break time. As we collected all the machines and put them back into the cart, we talked with the teacher about that day's happenings during the activity: what worked and what didn't, which concepts were more difficult, and which were easier to grasp for them. The children grabbed their coats and flew to the outside, some of them wandering around us and asking about what we were doing.

After we left the cart in its place, connected to the AC power for recharging, we aimed for the exit. We greeted some teachers gathered around the coffee machine, and one of them joked: "How come you're here again? You should be on the payroll already". The playground was now full of children running up and down of it, playing football and a thousand other games. A small girl came up to us and showed us her new book, which appeared to be not only readable, but also smellable.

Slowly, we inched through the childish tide and got into the car, talking about the day's most curious events. Infected with the childrens' joy, we crossed the countryside, which was waking up in anticipation of Spring's arrival. Back to the city. Back to the lab...

This vignette tries to convey the atmosphere and routines of a typical day in our observations and inquiries at the CRA[3] "Ana de Austria" school in Cigales. Readers less adept to written imagination can also refer to figure 4.4. This section will depict some of the main characteristics of the context of this particular school, extracted from the revision of the school's documental base [C. 09], as well as from qualitative analysis of the interviews and focus group held with teachers (see section 4.1.1) and from our own personal experience.

School's characteristics

The CRA "Ana de Austria" in Cigales is the head of a rural school spanning Cigales itself and three nearby villages (Mucientes, Fuensaldaña and Trigueros). The area of Cigales, located some 15 kilometers from Valladolid, is best known for its wine-making, the biggest industry in that zone.

The school has 12 primary and 6 elementary classrooms, harboring a total of around 400 students (around 300 of them in Cigales) and 42 teachers. Even if the composition of the classrooms and their students is heterogeneous, all the villages share a Common Educative Project (PEC). This

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[3]Spanish acronym for "Colegio Rural Agrupado", or rural grouped school. This term denotes a rural school where children from several nearby villages go for (primary) education.

Figure 4.4: Location and external appearance of the "Ana de Austria" school in Cigales

project establishes the main goals and principles of the school, derived from the ideal of "Educating for liberty, equality, solidarity, democracy and tolerance, respecting individuality and differences" [C. 09]. In most regards, this school does not differ greatly from other public primary schools in Spain.

ICT at the school

One aspect, however, where this school is different from other rural primary schools is the ongoing effort (by its community and specially the directive staff) to *gather technological resources* to support education and other educative innovations. Even if most Spanish schools are immersed in several institutional projects and processes to introduce new technologies in the schools, the principals of the school have tried, for the past decade, to go further in this regard.

Thanks to public investments from the autonomic government, computers have been acquired, initially to populate the so-called "computer labs". The executive board of the school, however, decided later to progressively integrate the new computers in all ordinary classrooms (an innovative strategy that is still not widespread in Spain [Pla06]): in the first place, a single (fixed) computer was placed in each class, and later, Internet connections were added to them, allowing for a whole new set of capabilities, and converting the classroom into a more complex technological ecosystem. The process continued with the acquisition of whiteboards and projectors, and finally, of digital whiteboards and wireless tablet PCs, mostly through collaborations with educational hardware and software vendor projects, under the umbrella of the DIM network [dIDyMD09]. Most notably, in the last years a Moodle virtual learning environment (VLE) [DSS02] for the school

has been installed, and is now used by most of the teachers (mainly for storage of digital educational materials).

Table 4.1 summarizes the current digital resources at the school. Yet, this process is still in progress, e.g. for the next academic year, the school is determined to expand this selection of resources with a number of netbooks.

Location	ICT Resources	Connectivity
Computer lab	12 Desktop PCs Laptop PC Projector Digital Whiteboard	Wired
Mobile ICT classrooms	2 carts with 12 laptops each 1 cart with 20 tablet PCs	WiFi
Common classrooms (21)	Desktop PC Digital whiteboard	Wired and WiFi
Library	Desktop PC Digital whiteboard	Wired and WiFi
Multi-purpose classroom	Desktop PC Digital whiteboard	Wired and WiFi
Tutoring room	Desktop PC	Wired
Teachers' room	Desktop PC	Wired
Principal's office	Desktop PC Laptop PC	Wired and WiFi
Head of studies office	Desktop PC	Wired and WiFi
AMPA room	Desktop PC	Wired
Not tied to a classroom	AVER cameras WACOM tablets Moodle platform (VLE) 2 TV+DVD+VCR sets	

Table 4.1: Current digital resources at the "Ana de Austria" school

Several factors have constrained the usage of all these computers and digital resources. In the first years, the lack of a clear *training* strategy for teachers in general ICT usage (not to talk about specific pedagogic ICT usage) was one of the main obstacles. Other often-cited obstacles to this usage are the lack of time and the high workload of teachers, which prevent them from attending any additional training activities, and also affect their ability to search for educational materials and design complex activities. This problem has been partly mitigated with ICT usage peer-training sessions, organized by the "ICT committee"[4], which take place bi-weekly for two hours.

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[4] A board of the school teachers who are most expert with ICT.

The resources at the school are very *heterogeneous* (in fact, in our observations we could observe at least 3 different kinds of digital whiteboards, several brands of laptop and desktop computers, not to talk about browser and Flash versions, etc). This heterogeneity may also be a problem, and in fact it proved to be annoying for teachers, as they revealed in the interviews. This kind of obstacle is more acute in the case of specialist teachers, who do not have a fixed classroom and have to migrate from one classroom to another.

Another side effect of this variety and quantity of ICT resources is the increasing *maintenance costs* that they imply. The resources that the autonomic government allocates to these kind of activities (software and hardware updates, troubleshooting, etc) are clearly not adequate for a school such as this one[5]. Thus, the principal and the most knowledgeable of the teachers act as "improvised technicians" when the need arises. This aspect of maintenance is seldom considered, either by authorities or by the school boards (at least, until problems start to surface).

Educative projects

As it occurs in most Spanish schools, the Cigales school is performing several educative projects, in order to help the school in integrating ICT into its educational activities (please refer to the school's website [C. 09] for more information). The most relevant ones are:

- *ICT Project* "the virtual school". This project is running since 2006, with the following goals: a) to integrate ICT in the teaching-learning process within the curriculum (specially to enhance collaborative work), b) to foster the development of a virtual communication space for the educative community (mainly through the existing Moodle platform), c) to foster the use of ICT as a teachers' personal and administrative tool, and d) to develop an evaluation model to determine the degree of ICT usage and its impact in the educational process.

- *Training project* "teach and learn competencies using ICT". This project defines a number of competencies related to ICT that both teachers and students should meet. Its actions are grouped in two blocks: a) to know and to use the school's ICT resources, and b) to elaborate a database of educational activities in order to foster the defined competencies.

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[5]According to the principal, the official technician visits the school once every month; if we consider that this school has around a hundred computers, we will arrive to the conclusion that in a single morning the technician cannot even *check* that every computer is working properly.

- Red TIC [red09] and Red DIM [dIDyMD09]. The external social network of the school reaches these two networks, aimed to supporting and promoting ICT usage in educational centers.

- Apart from that, ICT also appears prominently in most of the other educative projects of the school, even if their main theme is different (e.g. the environment, fostering reading, astronomy or other sciences). All of them include a technical side or a number of activities to be realized through technology.

As we can see, the "Ana de Austria" school has invested a lot of effort and money in obtaining ICT resources, and is now working on integrating them in their educational processes through a variety of projects. Even if several factors have hindered this integration, the school's teacher culture of high participation and peer-helping will certainly make any intervention to foster ICT usage more promising.

4.2.2 Teachers' beliefs and values

Nowadays we have a remarkable paradox in the school classroom: we have a wide variety of new technologies and resources, but we find that educative practice is still based around two "traditional" elements – the textbook and the teacher. As we saw in chapter 2, the beliefs and values of teachers are a very important factor, both for the integration of new technologies in the classroom, and for ascertaining why teachers act the way they do in the enactment of classes.

In this section we will reveal some of the main beliefs and values of the participant teachers from the Cigales school, both regarding education and enactment practices, and also about the usage of ICT in class, and specially about the GroupScribbles application to which they were exposed. These results come mainly from the qualitative analysis of interviews and focus groups, as well as from observations of real classes (see section 4.1.1). A more detailed account of these results is available in [VP09] (section 3.2).

Beliefs about education

There are several common beliefs that teachers in Cigales seem to share, specially regarding education and its practice. They could be briefly summarized as follows:

- Education is an *integral aspect* in the life of any human being. Thus, teachers are not only curriculum content transmitters, but also teach their students how to socialize, how to live.

- Teaching and the activities proposed by teachers should be *adapted to the context* and level of the students. The usage (or not) of technology is always overriden by this consideration.

- Since pedagogical contents should be tailored to the student level, and to the context and its constraints (in time, space or resources), adequate *preparation of classes* is considered a very important element.

- Children in the observed age span (K-6/7) *find it very difficult to collaborate*. This could explain (in part) the lack of collaborative work observed in classes. Some teachers believe that this could also be caused by the weakness of their initial training in this regard.

Beliefs about ICT and GroupScribbles

When asked explicitly, the participant teachers in Cigales also showed a surprising amount of similar beliefs and points of view about technology (with the exception of the principal, who is much more expert with technology than the rest of teachers). Some of these beliefs include:

- One of the main advantages of ICT technologies is their *motivating* capacities for students. This is thought to be because of the integration of different kinds of media (text, audio, video, etc) that they provide.

- The choice of media and resources (be them digital or not) is dependent on the group's characteristics. Thus, it is important to know the predominant learning styles of the group, so as to design activities and contents that are motivating for them. This basically means that technology is seen as *just another tool* to support teaching, rather than an end in itself.

- Teachers also show a certain bias to consider some technological tools more adequate for *certain subjects* (e.g. GroupScribbles was thought to be specially adequate for Natural and Social Sciences, because of its ability to display images to be commented or developed later).

- Most teachers, independently of their age or teaching expertise, showed a certain degree of *technophobia*. This general attitude is based on a variety of secondary beliefs, such as seeing technology as an *unreliable* tool, or the disproportioned *time it takes* to prepare an activity compared to the time it takes for students to finish it.

- Despite this lack of confidence in technology, most of the teachers expressed their opinion that one of the most useful features of technological tools is the capability to *store and retrieve activities* (thus allowing for *adaptation* and iterative *improvement* of the materials).

- Another point of agreement among all the teachers is that technology "is coming on strongly", and that *children should be taught about it* as an essential ability for the future (i.e. as digital alphabetization), no matter how afraid they are of it.

When asked about the concrete tool that was introduced in their classes (GroupScribbles), teachers also showed general agreement about several opinions:

- GS is considered *easy to use*, both for teachers with little technical training and for children in the age span analyzed (K-6/7).

- Other cited advantages of GS are its *flexibility* for on-the-fly adaptation and its affordances for allowing *collaboration* among students (e.g. how easy it is to brainstorm with it).

- Another common understanding about the GS tool is that it is limited only by the *teacher's creativity*. This can be seen as both an advantage or a disadvantage, depending on the ability (and inspiration) of the teacher.

Beliefs about enactment and improvisation

Regarding their practice in the classroom, the most commonly held beliefs and values are:

- A general *disregard* of the mechanisms of *improvisation* (as opposed to adequate preparation of an activity). This is allegedly due to bad experiences in the past, when trying to apply this technique.

- Paradoxically, all the teachers recognize that *small-scale improvisations* due to unexpected situations (e.g. if a student makes an interesting comment that prompts a little detour on the original lesson plan) are commonplace in the classroom.

- Bearing this in mind, it is natural that teachers believe that *improvising with technology* is more difficult, due to the lack of confidence with that kind of resources. Unfortunately, the unreliability of technology is also perceived as *one of the main sources of improvisation* in the classroom (e.g. when the network does not work and teachers have to resort to offline activities).

4.2.3   Knowledge: Background and training

Another important milestone in the investigation of any concrete educational reality is to know the background and past experiences of the main actors in the study (not to speak about the importance of these aspects that can be derived from the reading of chapters 2 and 3). In our case, before we get to know how (and why) teachers use technology in their classrooms, it is important to know the training and other exposure that they have received regarding ICT. The qualitative analysis of the interviews and focus groups (see section 4.1.1) allowed us to gather the following trends:

- The *motivations* for being a teacher were rather *heterogeneous* among the participants. In fact only two of them declared a clear vocational attitude in choosing such a profession. The motivations for choosing the CRA as their school were also varied, ranging from geographical convenience to the availability of ICT and opportunities for training.

- The level of *expertise* as teachers also was widely variable, with three of them showing more than 25 years of experience, while the rest were rather novice teachers (less than 5 years of experience). This also was reflected in the position they held in the school (only four of them had definitive positions, while the other four had to rotate yearly).

- The amount of *experience and training with technology* was much more homogeneous, and was rather basic (except for the principal, who has had much more exposure to it). Most of them could perform basic tasks with computers (web searchs, usage of text editors, usage of multimedia players), but few had received any specific training about didactic applications of technology.

- Most of the *training in ICT* that the teachers had received had taken place *in the very same school*, as part of the formal and informal training programs that the teachers themselves implemented voluntarily. This kind of training does intend cover the two aspects of technology, namely its basic usage and the educational applications of it.

- The lack of training in their *initial careers* could be seen as one of the major causes for their lack of *technical ability*. This is also the case with *collaborative practices* (supported by technology or otherwise), and it is striking that this trait is shared both by older and younger teachers.

- Again, the *lack of time* for adequate training is another possible cause for this lack of technical knowledge. This is specially the case with more novel (and specially itinerant) teachers, who have had much less exposure to technology in the past.

4.2.4 Pedagogical practice: Design and enactment of activities

In this section we will detail the results from the analysis of teachers' activity designs and enactments with GroupScribbles (see section 4.1.1 for more information on the analysis methodology). A fuller depiction of these results can be found in [VP09] (section 3.4).

Two prototypical examples

In order for the reader to better understand the nature and the range of activities that were designed and enacted during our six-month stay at the "Ana de Austria" school, we will briefly describe here two prototypical examples of teacher practice. The first example (A) is a simple "social sciences" activity, designed and enacted by a novel K-6 teacher (with two years of experience), while the second example (B) is a more complex "social science" activity enacted by a K-6 teacher with more than 25 years of experience, including a background in elementary school. Both activities were designed and enacted at approximately the same stage of the study, around the middle of our interventions (28 April 2009 and 16 April 2009, respectively), when just one training session had taken place. In fact, both teachers had similar levels of technical expertise and dominion over the GroupScribbles tool. The detailed analyses of these activities can be found in [VP09], in appendixes A and B.

Example A: Our cities, our villages   The design of this activity (and its enactment, which followed the design closely) consisted in a brainstorming of objects and buildings that appear in villages and cities. Then, among the presented ideas, students would have to choose which of them could be found both in a city and in a village. This activity was enacted by 16 students, working in pairs with one tablet PC for each pair. The flow of the activity can be seen in figure 4.5, and transcurred as follows:

1. The teacher explains the nature and goal of the activity to the students, dividing the class into two large groups. She uses her voice and the digital whiteboard for such explanation.

2. Students work in their private boards with tablet PCs, and post their scribbles to one of the two public boards.

3. The teacher evaluates the responses in front of all the class, orally and using the digital whiteboad as a support.

4. The teacher opens a third board and asks the whole class which of the proposed objects and buildings can be found in Cigales. She uses the digital whiteboard to execute the classification herself, once the correct answers are given orally.

Example B: Coins and bank notes   The design of this activity consisted in decomposing the cost of an object into the values of different coins and bank notes, in order to buy it. In the initial setup, a public board was created with 18 "clues", each of which had a simple arithmetical operation

Figure 4.5: Diagram representing the flow of an activity across social planes and media/tools (Example A)

(the solution of which was the number of the student that should solve the task), and the name and cost of an object (e.g. "Pen, 72 cents"). In order to help students in solving the buying task, paper coins and bank notes were delivered by the teacher. Once the buying task is solved, students have to classify the tasks according to the cost of the objects, to see if they are cheaper or more expensive than a certain other item. This activity was enacted by 18 students, working in pairs, with one tablet PC for each pair. The flow of the activity can be seen in figure 4.6, and transcurred as follows:

1. The teacher explains (orally and using the digital whiteboard) the mechanics of the activity.

2. The teacher initiates the assignment of tasks, asking randomly whose is each task, and later telling the owners of the task to grab it and put it in their private board.

3. Students grab the tasks and solve them, using the tablet PC and the paper coins.

4. The teacher mediates in the peer evaluation of the written responses.

5. If a response is not correct, the student grabs it again and corrects it in his/her private space, putting it again in the public board afterwards.

A second activity had been constructed over this one, and it was enacted as follows:

1. The teacher asks students to grab their solutions again, and to classify them in another board, to see if they are cheaper or more expensive than an example item.

2. Students use the tablets to classify their items.

3. The teacher evaluates the results in front of the class, orally and using the digital whiteboard.

Since there was still enough time for another activity, a third, unexpected activity was enacted. In fact, it was students themselves who voted which kind of activity would be enacted:

1. The teacher asks orally students what kind of activity (building on the previous two) they want to do next. A descending ordering of the costs of items is chosen.

2. The teacher asks iteratively who has the biggest number.

3. Students, one by one, put their scribbles into the right sequence, using the tablet PC.

Designs

As we have seen in section 4.2.2, teachers put a lot of importance in the concept of preparation and planning of the lessons. This, in fact, is confirmed throughout pedagogical literature [Sch99]. Thus, it is very important to know what kind of activities the teachers design, and why they do so.

Designs' topics We analyzed 31 activities performed with GroupScribbles in Cigales. Twelve of them were about Natural and Social sciences, eleven of them were about Spanish language and eight of them were Mathematics lessons. We also found activities that combined more than one of these areas, but this was a very uncommon trait.

Design process As we observed in the co-design sessions with teachers, and as it could be gathered from the notebooks of teachers (see figure 4.7), the creative process of designing an activity follows (coarsely) five phases:

1. The teacher considers which aspect of the curriculum the activity should cover (i.e. the *goal*, in blue in figure 4.7).
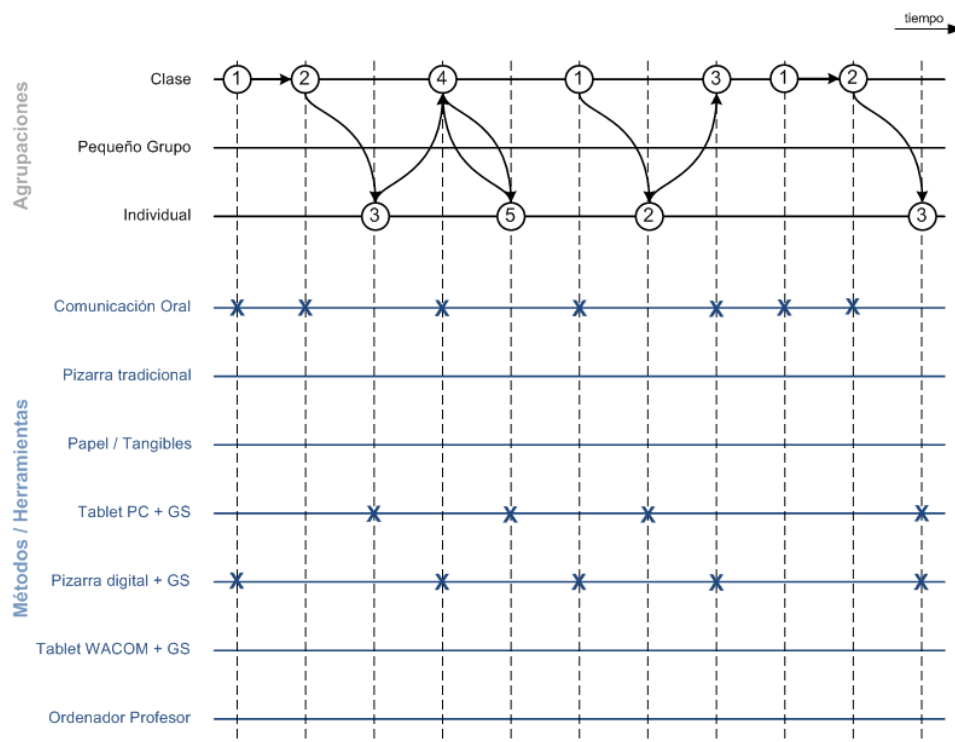
Figure 4.6: Diagram representing the flow of an activity across social planes and media/tools (Example B)

2. Determine which *resources* (sp. technological ones) are most suitable and determine the basic routines that should be internalized in order to use those resources (in this case, the resources had already been fixed, since it had been decided to use GroupScribbles).

3. Determine the *task flow* (i.e. the phases) that will constitute the activity (in green in figure 4.7).

4. Consider the flow of *groupings* (i.e. the social levels) that the activity will follow: individual work, small group or whole class (in red in figure 4.7).

5. Prepare the concrete designed *scaffolding* using the concrete resources (e.g. create and prepare in GroupScribbles a number of public boards for children to collaborate with). This is not reflected in the teacher's notebook since it is done *after* the design on paper.

We found that only one of the teachers put in practice an additional phase *after* the enactment, when she noted down the results of the activity and how it worked, presumably for later improvement of the activities or just for self-reflection (i.e. an evaluation phase).

pre-session activity

activity goal

description of the tasks that form the activity

task assignment among groups
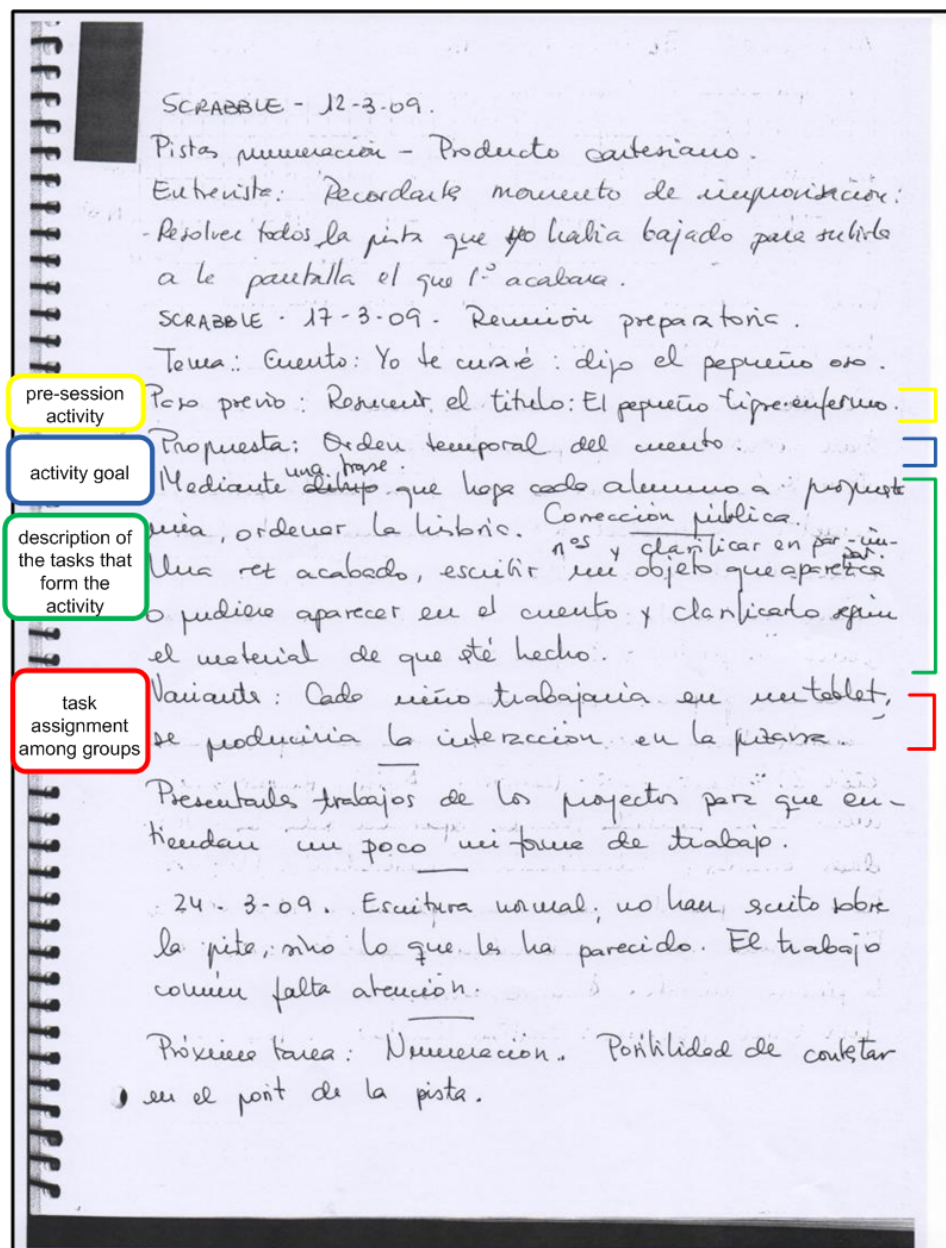
Figure 4.7: Excerpt of one of the teacher's notebooks, detailing the design of an activity

Design patterns We found that one could easily trace several common design patterns across most of the activities observed. For example, we found out that one of the most common patterns was to "brainstorm" ideas or questions regarding a teacher-proposed topic. Many of these patterns had been already uncovered in SRI's Contingent Pedagogies project [Int08],

although some of them were new. Table 4.2 summarizes the design patterns encountered, and their relative frequency of appearance (for a more detailed depiction of the patterns used in each activity, see [VP09], appendix B).

The temporal correlation of these patterns with the teachers was relatively high (i.e. each teacher tended to use mostly the same patterns over time). The reason why the teachers chose a pattern over another seemed to be related to their teaching experience, background and previous training; for example, experienced teachers tended to use more complex patterns (e.g. "Clues" or "Distributed Problem Solving") than novel teachers. Novel teachers, however, showed a clearer temporal evolution towards higher complexity than experienced teachers, who used more stable tactics as time went by. This can be possibly explained by these patterns (which are, in the end, a kind of computer use) acting as "invading species" in the classroom ecosystems, and spreading from teacher to teacher (see section 2.2).

Groupings It is remarkable that, with very few exceptions, all the activities with GroupScribbles were always implemented with two students working per tablet. However, the amount of collaborative work planned in the activities (e.g. that implied positive interdependency) was very low. This again can be explained as a pattern of use spreading among teachers throughout the classroom ecosystem, as well as a means to maintain classroom management issues (e.g. the chance for one tablet failing and stopping the class) down to a manageable level.

Enactments

Pedagogical practice is a complex and fluid phenomenon (in fact, as we saw in chapter 2, it is very much a *performance* phenomenon), and it is very difficult to disentangle the ideas, actions, values and beliefs that intervene and give meaning to it. Following Doyle's advice [Doy79], we will analyze the tasks as the basic unit regulating education. The sequence of tasks constructs a methodological model which frames the real significance of any educational project [Gim88]. We have taken from [Gim88] the main dimensions to structure our analysis.

Teacher practice organization In Cigales we have found that teachers normally resort to *simultaneous tasks*, either single tasks (i.e. the same task is to be completed by all students, as in example A above), or similar tasks (i.e. each student or dyad has to complete a different task, but with the same topic and structure, as in example B). This kind of organization has to do with the need to cater for students at different advancement levels, without segregating them; in many cases the difficulty of different activities is *adapted* to the level of the student (e.g. in example B above, the task to

Pattern	Description	# app	1st seen
Representing Information or Questions	Students generate questions or ideas reated to a certain topic	22	SRI
Classification	Organize post-its in a public board, according to certain hierarchies or classification criteria	15	SRI
Distributed Problem Solving	Each student takes a post-it from the public board, representing a different task, solves it and puts it back to the public space	9	SRI
Clues	Each student chooses a task, by solving a riddle (e.g. the consonants presents in the student's name)	9	Cigales
Team Quiz	Teams are formed inside the class, and points are awarded to each team according to the resolution of the activity sub-tasks	2	Cigales
Poll	Students vote which, among a set of options, is their favorite (probably for usage in a later activity)	1	Cigales
Pipeline	Each student takes a task from a public board, which represents a part of a bigger problem; after the student solves it, other student uses it for solving another sub-task, and so on.	1	SRI
Self-task	Students choose which is the next sub-task to be done (often using past sub-tasks as a starting point)	1	Cigales
Where on this image?	The teacher poses a question, students answer by marking over a background image in the public board	1	SRI

Table 4.2: Common design patterns encountered in activities in the Cigales school

be completed was customized by the teacher to the perceived level of the student).

When analyzing the *flow of tasks* in the activities observed, we found striking similarities. In fact, most activities followed the same basic flow:

1. The teacher explains the purpose of the activity to the whole class

2. The digital resources (i.e. the tablet PCs) are given to the students

3. The working groups are formed, depending on the tasks at hand

4. The task is executed by the students, individually or in dyads

5. The task is revised by the teacher

This basic flow has been observed both in experienced and novel teachers (e.g. both example A and example B above follow this general pattern). The differences are observed in a more fine-grained level, in the concrete *routines* that teachers use for the different phases, and how they were combined: for example, *novel teachers tend to maintain control* of the class by controlling the discourse and the digital media (e.g. digital whiteboard, see example A above), while experienced teachers give more leeway to *autonomous behavior* and release the control of discourse and resources to students (e.g. letting them correct incorrect answers, see example B above).

As we can see, the amount of *collaboration* that results from this kind of flow is fairly minimal, since the work in dyads is in many cases self-organized and no emphasis is put on specific forms of collaboration or communication among students.

We also can see, when comparing teachers' enactments with the designs, that there is a commond trend of teachers *not stepping out of the script*. As we saw in section 4.2.2, teachers consider improvisation as a kind of "taboo", that implies lack of professionalism, which could explain this trend. We did observe some *occurrences of improvisation* where the teacher let the students choose the next task to be done by them (see example B above), although the choice was not completely free, and the teacher always remained within well-known patterns and tasks. Moreover, the fact that we had already talked with that teacher about our interest in improvisation may disprove the authenticity of such events.

Media/tools usage   When analyzing the enactment of activities, we paid special attention to the orchestration among different social levels (as seen above) and to different media and tools that the teachers used. Regarding the usage of different media for teaching, we also observed a common pattern in almost all of the activities:

1. *Spoken* explanation of the objectives of the activity.

2. Delivery of the resources, also using natural social mediation (i.e. *speech*) to coordinate the process.

3. Explanation on the tasks to be completed, and how to reach the activity with the computers. Here, *speech is used in conjunction with the digital whiteboard.*

4. Students do the task using the *tablet* (either individually or in dyads)

5. During this task completion, the teacher walks about, solving student questions and doubts, or technical problems that may arise.

6. The teacher corrects the activity using *speech and the digital whiteboard*. In some cases, the teacher lets students do the corrections themselves using the whiteboard.

This flow is similar and parallel to the task flow presented above regarding the different social levels. It is striking that this flow is present regardless of teaching experience or technical expertise. Steps 3 to 6 may be repeated in cycles several times for different tasks, depending on the complexity of the activity and the available time.

4.3   Discussion of the results

In this chapter we have presented so far the methodology and results of our exploratory fieldwork in a certain educational context, more concretely, in five K-6 and K-7 classrooms in a school in Cigales (Spain). As the reader may remember, the goal of this inquiry was to get to know the context of the school, but specially to understand how a concrete technology (in this case, the GroupScribbles application) gets used by teachers in authentic scenarios, putting special emphasis on the design and enactment of activities, and the concept of improvisation.

The findings that we made when studying this context were arranged around four emergent categories: the context of the school, teachers' knowledge, teachers' beliefs, and teachers' practice. Figure 4.8 presents a brief schematic summarizing the most notable findings of the study. Please note the different arrangement of concepts between this diagram and the ones presented in chapter 2 (figure 2.1), which is due to the former being emergent from the field data (rather than categorized with respect to literature models); In chapter 5 we will attempt to reconcile both models.

Coming back to Ertmer's "barriers for integration" (see section 2.2), we could say that, even if the first-order barriers are being tackled successfully in Cigales (digital resources are available, and training programs are in place), several *second-order barriers* (e.g. the general distrust of technology, or the beliefs about how difficult it is to use collaboration or ICT in the
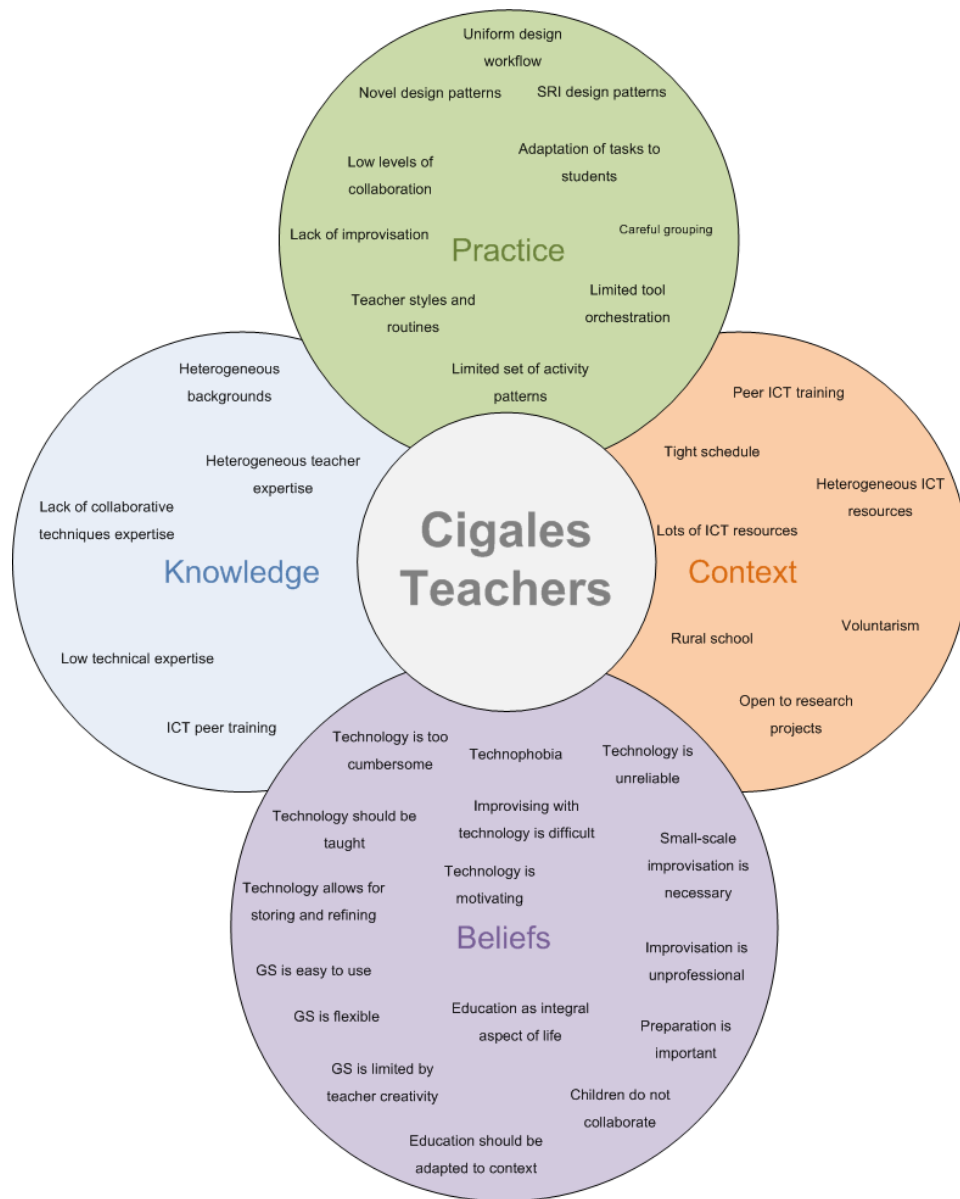
Figure 4.8: Summary of the field study's findings, along the four main categories considered

classroom) *are still standing*, hindering effective and innovative uses of ICT in the school.

In fact, in analyzing the *beliefs and values* of teachers, we have found that *technical training in basic ICT skills* (which is already being implemented in the school) *is not enough* to shift these intrinsic aspects of teachers. Thus, any attempt at an intervention towards a more integrated use of

ICT, specially in collaborative learning activities, should take these *intrinsic factors* into account, and target them as one of the first aspects to change, by making the teachers aware of them and, eventually, developing more effective ICT-supported practices.

Also, studying the teachers' pedagogical and technical *knowledge* and their backgrounds, it was interesting to note that, independently of their expertise or professional trajectory, teachers were equally *eager to try out new methods* and technologies, always *within the constraints* that the curriculum and the education of children as the ultimate goal imposed (e.g. activities should be aligned with the curriculum, teachers had limited amounts of time for designing activities, etc). These constraints were specially acute for itinerant teachers, who amount to a big percentage of the school staff. These factors make a future intervention promising, although they also call for a careful planning of the actions, taking into account all the *constraints* that this particular context imposes.

However, let us remember that *pedagogical practice* in the classroom (i.e. design and enactment of classes) was the main focus of the study. We found that the educational reality of a school is a *complex*, multi-dimensional entity, and that its analysis is equally complex, requiring multiple sources and long stays in the context, since one must take into consideration not only extrinsic, easy to observe factors, but also intrinsic ones (e.g. beliefs), which are much more difficult to experience and measure. The *performance* of educational activities is specially hard in this regard, due to its fluid, ephemeral nature. Despite this complexity, the observations made in the classroom encountered teachers managing their classes with relative ease and naturalness. This induces us to think that there exist simplifying mechanisms that reduce the complexity of classroom practice down to something manageable for them [Gim88]: the role of *tasks as organizing units* towards certain educational goals.

We found out that the teachers *designed* remarkably similar activities with GroupScribbles, regardless of their background and expertise. Not only that, but also the teachers followed the same *design process*, which sequentially took into consideration a) the curriculum and other goals, b) the available resources, c) the student groupings, d) the sequence of tasks and e) the concrete implementation with the selected tool. These commonalities may be caused by the existence of common design routines to reduce complexity [Gim88], the viral quality of pedagogical practices and uses [Gim88, ZF03], or the fact that pedagogical activities tend to stabilize over time, after an initial period of reflection and comparison [Gim88].

It is also remarkable that many of the *design patterns* observed in Cigales with GS (i.e. the kinds of building blocks that teachers used to design activities) had already been uncovered in SRI's Contingent Pedagogies project [Int08]. This could be caused by the applicaton's inherent capabilities or *affordances*, thus suggesting a *link between the tool's affordances and the*

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activities that can be designed with it; a relationship that could be worth exploring in the future. However, the appearance of new patterns not recorded by GS's creators also suggests that designing activities is a *creative process* where the creator (the teacher, in this case) also brings in a whole new set of experiences and knowledge that the tool designer cannot possibly foresee. Also, the continuity in the usage of the same patterns by the same teachers, regardless of experience, indicates that these patterns are not easily changed or learned (and thus making them similar to beliefs and values in this regard).

It is also important to note the differences in the designed activities' *complexity* between novel and experienced teachers. Not only do expert teachers show command over more numerous patterns, but they also combine them in more imaginative ways. A study of the effects of this complexity in student learning could be in order, as could be the design and implementation of tools and training programs that help novel teachers achieve this kind of complexity faster.

Teachers also showed a remarkable interest and careful planning in the *groupings* for the activities, normally in dyads, and following one of two strategies: a) to join students with disparate academic levels in the subject, or b) to join students with similar academic levels, if one or the two of them showed competitive behavior (so that one student would not monopolize the resource). These strategies present teachers as an essential element in the classroom due to the *extensive knowledge of the students*, and also can be seen as the seed of beliefs favorable to *collaborative work*, even if teachers' initial training in this regard is clearly lacking. Additional training in this area would certainly be needed if any real CSCL scenario is to be implemented in Cigales, but the attitude of teachers makes this kind of intervention promising.

Regarding the *enactment* of activities, the general flow of activities (which derives directly from the design of the activity) remains very similar in all cases across teachers. However, the concrete way the discourse and the tasks were implemented could not be more different: each teacher has his own (small) set of *routines and patterns*, which mirror their beliefs and their background (e.g. a teacher who was a former elementary-level teacher shows more small-group routines and fostering of autonomous behavior, which are typical in elementary education), a fact that has already been covered in literature [Gim88] as a way of dealing with the complexity of orchestrating the activities of a group of students, to reach multiple educational goals [Sch99].

Bearing in mind that the study of *teacher improvisation* with Group-Scribbles was the original goal of this set of experiences, we must acknowledge a tremendous *lack of this kind of behavior* in the teachers at the Cigales school. The frontal opposition of teachers to the concept of improvisation (versus careful planning of lessons) may not be such a surprise, but it is

certainly surprising that, even the small-scale improvisations that teachers do consider (and even think beneficial for a meaningful and motivating education), are rare almost to the point of non-existence. We basically found two kinds of improvisation:

- *Planned improvisations*, in which the teacher actively inserts an improvisational element, a wildcard in the design of the activity (e.g. when a teacher lets students choose what to do next with the activity results, see example B above). However, this kind of improvisation is not completely free, and the teacher maintains control of which options are "legal" and which are not. Thus, the improvisation always remains among the patterns known to the teacher (e.g. in example B, the teacher only allowed activities that resembled tasks already seen in past lessons).

- *Unexpected design changes*, which may be brought about by an error in the design of the activity, or by student feedback. These changes can be seen as an "on-the-fly redesign" of the activity, which is dependent on the flexibility of the tool to allow for such changes in the design.

Thus, we find that *improvisation* in teacher's enactment may be sometimes necessary, but it is not commonplace in authentic teaching scenarios. In any case, we confirmed the assertion, seen in some literature sources [BL89, Yin87], that *experienced teachers* are much more prone to this kind of behavior, not only because of the wider variety of patterns that they can command naturally, but also because of their dominion of classroom dynamics and management (thus making it easier to maintain the discourse and the students' attention while staying inside the "comfortable patterns" zone of the teacher).

Regarding the use and *orchestration* of different tools and social levels, our teachers showed a remarkable preference about using *speech* as the main vehicle for advancing the activity flow, specially when addressing the whole class. The use of *technological tools* was reserved to *individual work*, or as a *secondary support* for task review and correction, in the case of the digital whiteboard. This *limited set of orchestration patterns* point towards a lack of technical knowledge about the tools' affordances, and about how they can be exploited towards concrete educational goals. This would certainly be a primary point of action in any future intervention that aims to improve this aspect of teacher practice with ICT.

Chapter 5

Discussion: Putting everything together

In this chapter, we will try to establish useful *relationships* between the diverse results presented so far, both from the review of literature, the analysis of a CSCL tool and from our own work in a real school context. These relationships will be the first step in building a *conceptual framework* that will eventually help us in *designing and implementing our future interventions* in the Cigales school (and in other educational settings). We will also derive from this material a number of recommendations for the design of CSCL tools and processes that support teacher enactment of CSCL activities. These two elements will be the first milestones in the proposed design-based effort towards better CSCL tools and processes that support teachers in the enactment of CSCL activities in authentic computer-integrated classroom scenarios.

5.1 Towards a conceptual framework for teacher enactment

5.1.1 An extended teacher model

If we take the teacher models presented in chapter 2, and relate them to the fieldwork conducted in Cigales (see chapter 4), several common concepts and categories can be spotted. In fact, we could try and propose an *extended teacher model* that synthesizes both, trying to explain how and why teachers decide to act as they do when they are in class. This model is presented in figure 5.1.

In this model, the teacher is represented by a number of *intrinsic qualities* that affect their practice as teachers (both when designing activities and when enacting them): their *knowledge* (including pedagogical knowledge, technical knowledge and past experiences as teachers), their *beliefs* (about
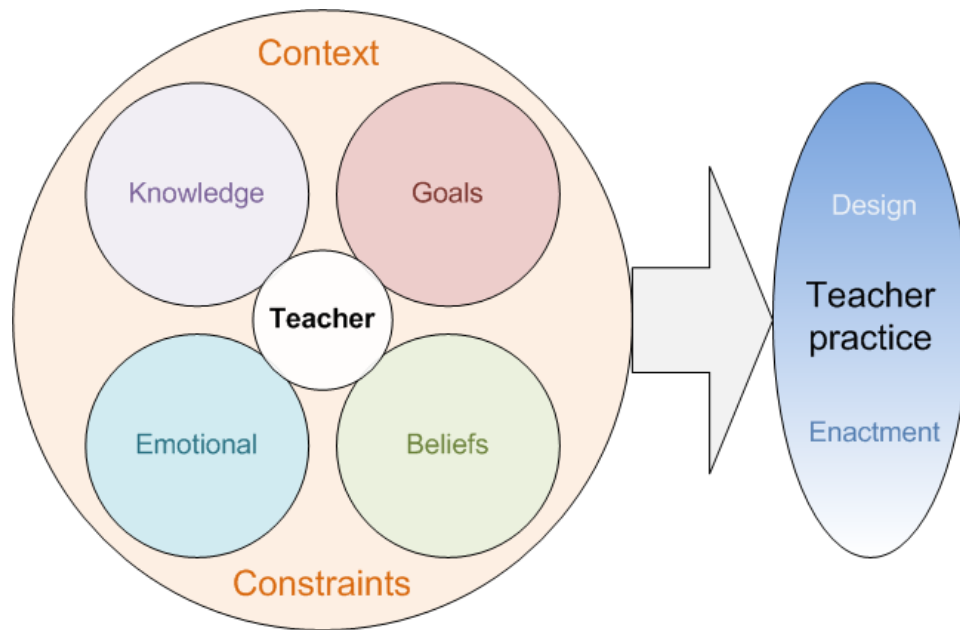
Figure 5.1: A proposal for an extended model of teachers' design and enactment

education, about ICT, etc), their *goals* (educational goals that a teacher has in mind in a certain moment), and also other *emotional factors* (such as their motivation, whether they like the subject or not, etc). The interactions of this intrinsic teacher model with the concrete context and the restrictions it imposes, is what will produce the final observed behavior, that is, *teacher practice*. We could think of the context as being a kind of filter that takes all the possible courses of action that the teacher *would consider* and restricts them down to a smaller set of actions that the teacher *can really* take, and from which the final course of action is chosen. Yet, we should not take this simile too far, since the context interacts with the intrinsic factors in very complex ways, shaping them as well as shaping the actions that are possible.

This kind of model can be applied both to the process of designing as well as to the enactment of the lessons, since the same factors seem to be present in the minds of teachers in both situations. In fact, as we saw when reviewing the nature of improvisation as a way of real-time composition (section 2.3), *design and enactment* could be seen as *two sides of the same coin*: there is design (or, at least re-design) in the enactment and disciplined improvisation of activities; and also, the teachers try to imagine and predict the enactment when they design an activity. Both activities imply an intent of predicting and influencing learning outcomes, with a set of educational goals in mind (static goals when designing, but more dynamic and fluid goals during enactment).

We hope that this model will help us in explaining the actions of teachers in class, and it will serve as a conceptual framework that accounts for the factors that we, as researchers, should keep in mind when intervening in the educational setting of Cigales (or any other classroom setting, for that matter). As the reader may notice, not all the factors mentioned here have been properly studied in the fieldwork described in chapter 4. Some of them can be extrapolated from existing data, but others will have to be looked at in more detail in future studies (e.g. the emotional factors or the educational goals).

However, it must be kept in mind that this framework, however useful, is just a *tool*, and must not be mistaken with reality. In fact, following the principles of grounded theory and design-based research, this model should be compared with any new uncovered data (including existing literature), and modified (or ditched completely) if necessary.

5.1.2 Improvisation and flexibility

If we take a look into teacher practice as it was observed in Cigales, and as most literature portrays it, we find that expert teachers show more flexible behaviors, resorting to improvisation or contingency (i.e. uncertain outcomes or task flows) more easily. However, in Cigales we have encountered that *good planning is much more valued* by teachers at all levels of expertise than it is improvisation, and all teachers, even the most experienced, do not stroll out of the known path of the script without a really good reason.

What this indicates is that maybe improvisation itself is not such an interesting topic in real computer-integrated classrooms as we originally thought, at least not in its more obvious forms (such as improvising large parts of a lesson). As the research study went on, the importance of *small-scale improvisations* became more noticeable, as did the ability, both in teachers and in the technological tools, to *change in real time* some of the characteristics of the teachers' planned activity flow. Thus, we may conceive *improvisation* (at least, the kind of improvisation that we are interested in) *as real-time redesigning of learning activities*. This improvisation can be completely *emergent* from unexpected classroom events (e.g. students not showing up, unanticipated group performance) or somehow planned in advance by the teacher in a sort of *contingent* plan. These contingent plans usually depend on some sort of real-time assessment of the students and, thus, features for such assessment would be very valuable in contingent activity enactment.

This conception carries several implications: first of all, that we should not abandon the study of *activity design practice* (both for our research and for eventual training of teachers), but rather delve deeper into it, trying to decompose its larger best practice structures (e.g. macro-scripts) into smaller patterns, mapping them to educational goals and seeing how

those patterns can be applied in real-time. Also, that a first approach to the design of useful enactment tools can be done through the analysis of *design/authoring tools* (since design and enactment are essentially similar activities) or, alternatively, through tools where the *frontiers of design and enactment are diffuse*, such as GroupScribbles or wikis.

Another important aspect that appears both in our fieldwork and in the reviewed literature is the fact that *teacher improvisation is not completely free*, not even within the structure of the activity plan. Rather, we have found that all improvisation seems to be *pattern-based*, selecting the "improvised" course of action from a limited set of well-known routines that the teacher can combine creatively in real-time. This also explains why novel teachers (who may not have internalized many – or any – of these routines) are so afraid to improvise. We believe that uncovering these *improvisational patterns*[1] in real teacher practice (or deriving our own patterns from CSCL literature and other sources) should be one of the main challenges to undertake in the future of this research effort. These patterns could later be used to design *CSCL tools* that support them, but also to use them as *source material for teacher training* since, as we have seen, the tools alone do not suffice if the teachers have not internalized the goals and the techniques to be used in these flexible enactments.

Thus, even if the path proposed here has not often been trodden before, we should not ignore the potentialities of past CSCL research, specially in the area of activity design through *scripts*. We propose to uncover the smaller routines that make up successful CSCL scripts, the LEGO™ building blocks that can be used to recognize how the goals of a script are achieved, and with them, the intrinsic constraints of the script. This kind of knowledge, if internalized by teachers, would allow them to operate with CSCL scripts under a variety of forms and circumstrances, and also to *create their own* scripts tailored to their context and their needs[2]. We believe that this kind of teacher empowerment, allowing them to create new scripts easily, without the need for specialized help (similar to the one brought about by wikis, blogs and other Web 2.0 phenomena, which allowed anybody to create their own web pages and to do it collaboratively), would be a considerable advancement in educational practice, both with and without digital technologies.

We must also mention a concept that has already been mentioned in this report, which is the *gap* that exists today between the level of *formalization* required by machines in order to interpret and scaffold a CSCL activity (see, for example, the IMS-LD specification [Con03]), and the *fluidity* of

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[1]This concept of improvisational patterns is very much akin to Demetriadis and Karakostas's *adaptation patterns* [KD09], except without the emphasis on adapting macro CSCL scripts.

[2]In fact, the Collage tool [HLVFAP+06] developed by the GSIC-EMIC group was a first step in this direction.

classroom enactment, where a myriad of different occurrences can emerge. Up to now, researchers have tried to cover this gap by abstracting and classifying classroom occurrences in order to get a limited set of parameters, roles and tasks that a computer can recognize. However, given that in a real classroom (specially face-to-face) much of the information and interaction happens *outside of the machine*, and requires human intervention for its interpretation, we could posit *freeform, flexible tools* (such as wikis or GroupScribbles) as a way to bridge this gap, driven by human creativity and initiative, rather than by machine automation. That is, we propose *using teachers' capacity* for pattern matching and recognition as the way to take the infinite possibilities of the classroom and map them into our limited set of patterns and building blocks, interpreting what is the situation, and deciding any remedial actions to be performed. In this case, the scaffolding provided by technology will necessarily be *lighter* than it is in usual CSCL scripting environments, even if mechanisms (such as advice based on interaction analysis techniques) could be added to it as a complement to the teachers' own perceptual powers.

We hope that this document has clarified some of the aspects that surround flexibility in computer-integrated CSCL classrooms, but it also leaves a number of *open questions* related to it, such as:

- What is the relationship between these concepts of flexibility and improvisation, and the orchestration of different tools? Are there relationships between the improvisation patterns mentioned and the choice of tools used for enacting them? that is, those patterns are tool-dependent or tool-independent?

- We have found (both in literature and in our field study), a strong emphasis in the creativity of teachers (specially when designing, but also during enactment). Can novel teachers be taught to be as creative as expert teachers by any means? Moreover, is this creativity (e.g. the ability to design original activities) necessarily good for the students' learning outcomes? or is it just a case of aesthetics and "teaching as art"?

These are interesting questions, but right now they fall outside of the scope of our work (and will probably remain so in the near future). Thus, they are left for the reader to consider, maybe to drive future research inquiries.

5.1.3 Orchestration

Regading the issue of orchestrating different tools and media across different social levels, we have found a much more diffuse field, with not so many preceding studies or clear theories about it. Probably the main conclusion

about orchestration so far is that *CSCL macro scripts* (with their description of tasks, groups, roles and tools) and *scripting environments* (which execute those scripts), are the most common way that has been found to *liberate teachers* from the burden of orchestrating collaborative activities or, at least, to guide them through that process. Yet, if we want enactment of activities to be flexible, we will also need the capacity for *flexible, on-the-fly orchestration*. In fact, we could say that there are two kinds of orchestration: designed orchestration (which happens when the teacher or designer plans the activities, tools and groups that are going to be used) and *enacted orchestration* (the one that happens during the execution of the activity). We are specially interested in the latter kind, which is basically the performance of the designed orchestration, variated and mutated by the unexpected occurrences in the classroom.

Regarding the *orchestration of tools*, we have seen in Cigales that teachers show a limited range of orchestration patterns. If we compare this fact with their asserted knowledge (or lack thereof) about the digital tools at their disposal, we arrive to the conclusion that, in order to orchestrate different tools successfully, *teachers have to know their tools* and, specially, the pedagogical uses of those tools (following the orchestration metaphor, conductors have to know the instruments, their range, and the sound effects that each of them might achieve). A closer study of the different tools and media that we can find in the classroom (e.g. through analyses such as the ones presented in chapter 3) would be in order, focusing specially on *pedagogical tool uses* and the goals they achieve, rather than in the technical aspects of the tools themselves. The ecological perspective of integration depicted in section 2.2 could also help us explain and predict why these uses might (or might not) be successfully integrated in the classroom ecosystem.

The importance of *learnable patterns*[3] (in this case, tool usage or orchestration patterns) could also be useful in this area, if we want teachers to combine different tools in real time during their enactments (we could coin the term *improvisational orchestration*). Thus, the discovery of this kind of patterns, as well as patterns that use combinations of tools, could be a step towards better orchestration. Afterwards, adequate training on those patterns could be given to teachers in order for them to internalize the patterns. In fact, it could be argued whether these "improvisational orchestration patterns" and the "improvisational patterns" presented above are the same thing; if the patterns include which tools and groupings should be used, we could certainly say that *these patterns may help in flexible orchestration of activities*.

Again, a possible approach to the discovery of these patterns would be to *analyze* the orchestration that well-known *scripts* in literature provide in order to distill orchestration patterns from them. Also, *engaging teachers in*

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[3]Learnable by teachers, that is.

the design of activities that orchestrate different tools towards the completion of a set of educational goals, and extracting patterns from them would be another option. To this aim, the development of *tools that guide teachers* in the orchestration of tools[4], its problems and possible solutions, could prove invaluable both for designing activities and for the internalization of patterns that can be put to use during the enactment of lessons.

This document has tried to clarify the murky waters of current research on orchestration of collaborative lessons, but there are still large patches of *unexplored land* in this area...

- The area of *multi-modality in CSCL* (e.g. the use of multiple tools simultaneously for educational purposes) has not been properly reviewed in this document, due to lack of time and space. Since there exists a considerable number of publications on the subject of the usage of multiple media for learning, reviewing this kind of literature could be helpful in deriving new orchestration patterns that can be used in the design of tools that support orchestration, as well as to be internalized by teachers.

- With the usage of multiple tools in a script or lesson workflow, the problem of *data flow among activities* appears. Currently, in most scripting environments this is done manually, and it could be argued that the automatization of this process could be beneficial in order to liberate teachers and students from that chore. However, adding flexibility to a scripting system will make this matter much more complicated. This could be a complex problem worth its own PhD thesis. Taking into account that activities and discourse in computer-integrated classrooms happen partly outside of the machine (e.g. paper activities could potentially be combined with computer ones), we think that the costs of solving this problem outweigh the benefits in our context, and therefore, we will abstain from touching the issue.

5.1.4   Unified conceptual framework

Figure 5.2 tries to synthesize all the concepts mentioned so far into a single conceptual framework. We hope that this kind of concept map will help us in designing or modifying any CSCL setting intended for enactment, by reminding us of the factors that shape the use of such a tool: the processes that teachers follow during enactment, and why they do it so.

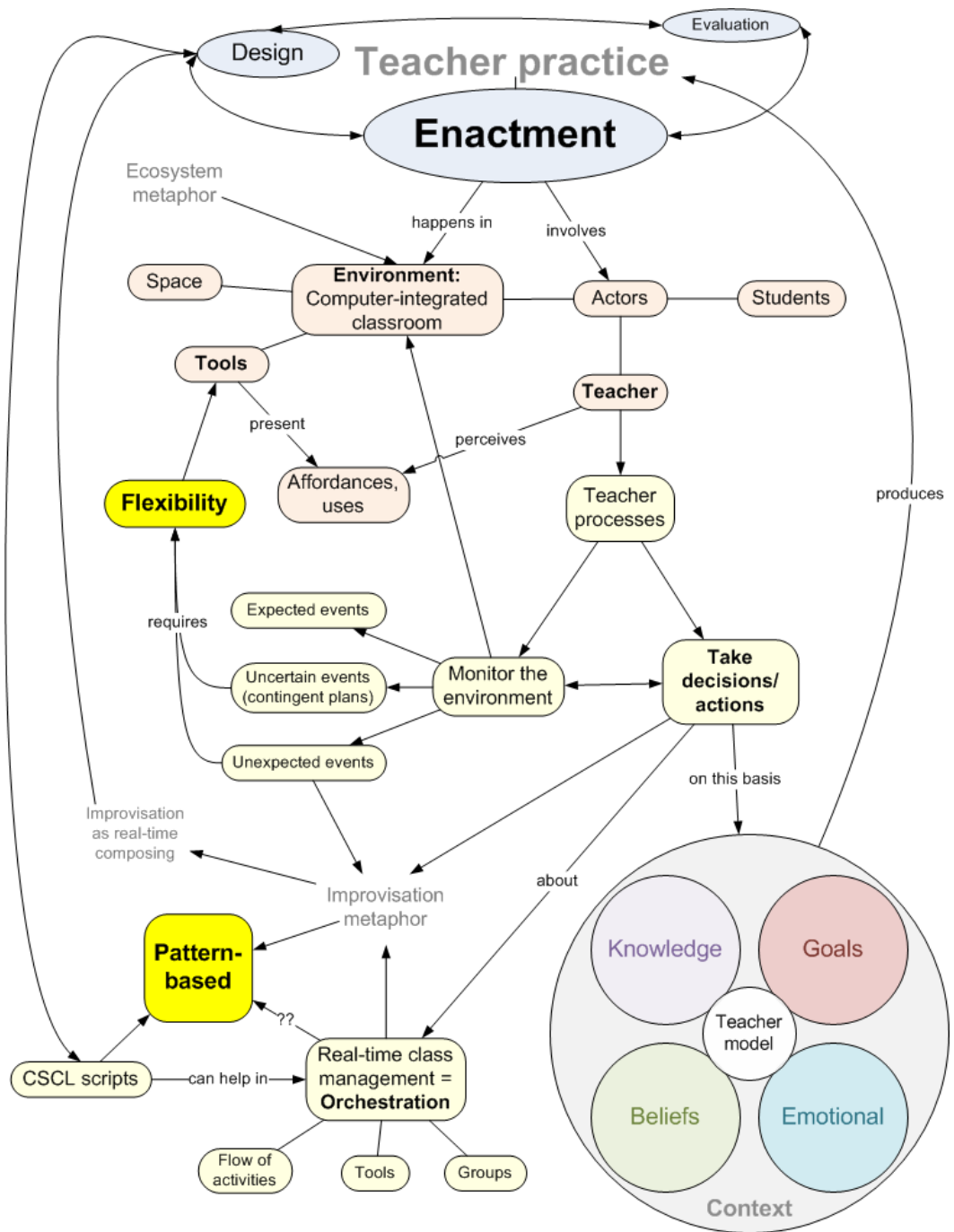[4]Again, the Collage/Gridcole system developed by the GSIC-EMIC group comes to mind.

Figure 5.2: Conceptual framework of teacher enactment of CSCL activities in computer-integrated classrooms

5.2 What this means for us: Ideas and recommendations for CSCL tool design

5.2.1 Consequences for a design-based research

If there is one single conclusion that can be drawn from the past six months spent in Cigales and from the literature review that we have done in this document, it is that the *concrete context* and the *intrinsic factors* of teachers (knowledge, goals, beliefs and emotions) *play a crucial role* in any change to be done in the classroom (specially technological changes, but also pedagogical ones). In any future intervention in Cigales, we should take teachers' beliefs and attitudes very seriously, and be specially careful in how we expose them to new technologies and processes, so that they can be made compatible with these beliefs or, alternatively, working towards changing those beliefs. This puts a powerful stress in *teacher training* in future interventions, both about technical abilities and about pedagogical patterns (e.g. collaborative techniques), but specially about *integrated uses of both*: we cannot expect teachers to integrate technology with pedagogy if we present either side separately to them.

From the use that teachers made of the GroupScribbles tool, we have learned that *good tools are not enough* for effective pedagogical practice. It is useless having a flexible enactment tool if teachers do not know how to be flexible, or think that flexibility is not desirable. Again, this conclusion points towards the need for adequate training, not only about *how* to use the tool, but also about the *goals* and *rationales* behind those uses. In this regard, the methodologies of training used in the Singapore experiences with GroupScribbles (using pen and paper counterparts before presenting the tool itself, see [NLC08]) provide a promising approach for teachers to apprehend and contextualize the uses of that technology.

This combination of traditional (pen and paper) and new technologies provides a reminder of an important fact in computer-integrated classroom settings: *old and new technologies coexist* in these classrooms [HBZ93], the same way as *old and new pedagogies* do. As Dillenbourg points out [Dil09], we should not get carried away by our research and think that in a good lesson only collaboration and computers are needed. Rather, we should discover which tool or process is adequate for each task (be it individual or group work, paper-based or silicon-based) and try to uncover the synergies that could be brought about by spreading the scaffolding among different tools and media [Tab04].

Also, the limited usage patterns of GroupScribbles in Cigales (which was used mainly for the evaluation of student knowledge) indicates that *each tool* may be most effective towards a *limited set of educational goals*. Thus, we should not restrict ourselves in the future to experiences using GroupScribbles, but rather analyze and test different tools for different purposes, in

order to gain insights on the goals that best match each tool, and eventually uncover any *orchestration patterns* that can help in designing and enacting lessons with multiple tools. However, as the number of tools increases (and with it, the number of possible combinations of tools), the problem of *multi-instrumentality* can become too complex too quickly. Thus, it is advisable to restrict ourselves to a small number of tools, at least in the first stages of our research.

And finally, we should not forget that all these theoretical and technological constructs, even if they prove to be interesting research, also represent an amount of knowledge, changes and evolution that affects *a concrete real setting* (the context of the Cigales school). Thus, we should not only think about what is the best way to provide training to already overworked teachers, but also what is the best way to make these changes *sustainable after our departure* from the field. In this regard, formal courses and written documentation seem to be the first option that comes to mind, but we should also consider *other approaches* such as informal learning methods or communities of practice, as potential ways of making the knowledge generated sustainable, but also to help in *disseminating* and *evolving* it after the researchers leave and their PhD thesis are over.

5.2.2 Recommendations for CSCL enactment tools

And while we are talking about tools, the reader might be surprised about the lack of emphasis that has been put so far in the proposal for new CSCL tools (or the modification of existing ones), taking into account that it was one of the author's main goals for this research work (see chapter 1). However, the conceptual framework that was presented in this chapter, and several other concepts that have appeared throughout the document, can be used to formulate the following *recommendations* about designing CSCL tools that support teacher enactment in computer-integrated classrooms:

- Take into account the *intrinsic factors of teachers* (knowledge, goals, beliefs, emotions) when designing the enactment tool. In a strict sense, that would mean designing a different tool for each teacher, which is probably not feasible. But this recommendation could be applied in a different way, using *general features* that teachers (or, at least, teachers in a certain kind of learning scenario) tend share. For example, the beliefs and technical abilities of teachers in Cigales would prompt us to think about easy to use, reliable tools, and tools that use metaphors familiar to the teachers (blackboard, sticky notes, pencils...). These features would also be appropriate for most Spanish primary school teachers.

- Matching tool features and intrinsic factors not only would help in designing tools that teachers find natural to use, but also would be very

valuable in designing tools that are *easy to integrate* in the ecosystem of the classroom. In this regard, it would also be very valuable to design the tool in such a way that it *blends well with existing species* in the classroom (e.g. tablets, computers, or even blackboards and paperware), in a form of symbiotic "combined affordance"[5]. Again, the existing tools vary from classroom to classroom, but some generalizations could also be made. A derivative idea of this one would be to have a tool that can be managed differently depending on the tools that it is used in combination with, in order to leverage the affordances of the accompanying tool (e.g. a tool that can be used differently if accessed through a tablet PC or through a digital whiteboard).

- Perhaps one of the main findings of this exploration is the fact that improvisation is mostly *pattern-based* and that expert teachers mix and match internalized patterns flexibly and creatively in their enactments. Thus, finding and exploiting these improvisation patterns would be of the utmost importance for any CSCL tool designer that intends to support teacher enactment. These patterns would have to provide some sort of mapping between educational goals (which is the foremost element in the enacting teacher's mind) and the flow of activities, groups and tools (or, rather, tool uses/affordances). The ability to combine these patterns *flexibly*, in real time, in order to change the flow of the activity would probably be the biggest challenge for designers, but also there may lay the secret for their success.

- Another important aspect of this concept of improvisational patterns is that they should be *internalized by teachers* in order to use them improvisationally. This idea technically is not a requirement for the design of the tool (rather, it is for the training of its users), but designers could find ways of subtly introducing it into the design (e.g. by presenting only a few patterns to the teacher, and increasing the availability of further patterns as the first ones are dominated).

- Another interesting idea for the design of CSCL enactment tools is that *improvisation is a form of design* (a lightweight, rapid form of design) and thus, improvising a CSCL activity would use the same principles as designing it (with the restriction that only a few, simpler principles would probably be available in the mind of the teacher during enactment). This idea hints at tools (like GroupScribbles) where designing an activity uses the same metaphors and interfaces as enacting the activity.

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[5]A good example of this kind of feature – albeit with specialized hardware – can be found in the tangible system described in [JZS$^+$09], which uses paper cards as interfaces with the computer system.

- The issue of how to help teachers in *orchestration* is less clear for the tool designer. It seems that there exists a *tradeoff* between the amount of *support* (or scaffolding) that computers can give to the orchestration, and the *flexibility* of the systems. Yet, this relationship may not be a tradeoff at all, and be just a side effect of the conception of a script. Using *patterns* (as opposed to scripts) as the "unit of enactment" could be a way of circumventing this tradeoff. This point, however, remains still unproven.

- Many scripting environments try to reduce the cognitive load of teachers and students by hiding the complex structure of the script from them (e.g. just showing the task at hand). An alternative way of supporting orchestration of CSCL activities would be to *show* in some way the structure and progress of the script (either on a task-basis or on a pattern-basis), and make it possible to navigate and modify its structure as it progresses, allowing to go back and forth between activity phases.

- As a closing recommendation, it is very important that we do not forget about the other main actor of the enactment: the student. The kinds of metaphors and contents that the tool supports will have to match the coginitive development of the student. Thus, even if both tools are very flexible and easy to use, a wiki might not be as suitable as GroupScribbles for K-6 children, since they are not used to typing or devising long text pieces. The ability to exploit the above recommendations using very different interface metaphors adequate for each student level will be another important challenge for the CSCL tool designer.

With these recommendations in mind, a number of flexible CSCL tool ideas and modifications could be thought of. Here we list a few of them, which could be used as first stepping stones in future interventions in a computer-integrated classroom:

- GroupScribbles has proven to be a worthy option for studying improvisational teaching and flexibility in CSCL. This, coupled with the fact that teachers and students consider it appropriate for primary school level education, makes us think that we should not abandon the work with this tool. We could try to use it to discover improvisational patterns, and later try to to incorporate into GS ways of making the enactment of these patterns easier. We could also try to follow the same design principles used in GS (simple, well-known metaphors, fusion of design and enactment, limited set of tools) to design other CSCL tools adequate for different educational goals.

- A wiki-based collaborative learning activity authoring and enactment tool, in a similar vein to the one presented in [DN09] could prove interesting, due to its flexibility and the fact that designing and enacting activities in a wiki is largely done in the same way. In our case, more emphasis should be put in the improvisation and orchestration patterns that have been mentioned, and how the wiki could implement them, in order to advise and support teachers in making the appropriate changes in the lesson workflow during the enactment of activities.

- It is also worth noting that, while wikis seem to be the first tool everybody looks at when trying to empower non-technical end users (such as teachers), they were designed with a clear goal in mind (easy generation of static content). In our case the goal is substantially different (easy generation of lesson designs – which are somewhat static –, but also of lesson enactments – which are quite dynamic). Thus, looking at *other kinds* of Content Management Systems, or even developing entirely new ones, should also be considered.

- Regarding the orchestration of different tools, a sort of "orchestration wizard" that guides teachers through the process of assigning resources to the different tasks according to their educational goals could be devised, once our knowledge of such matters has grown. The work in this direction could be seen as building upon the work in CSCL tool searching done by the GSIC-EMIC group in [VGBLGS$^+$08] (Ontoolsearch), but adding additional concerns that are not in the original design, such as educational goals or the technical ability of teachers with the tools.

- Another approach that could be taken is attempting to foster the awareness of teachers with tools (or tool enhancements) that help them in remembering the structure, properties and the goals of the activity they designed, during the enactment (e.g. an activity workflow visor, or a graphic representation of the activity goals, or a list of the available tools and the goals that could be attained with them). Even if these tools do not automate anything, they could prove a good help for teacher practice and self-reflection.

In fact, another tangent direction that might be followed regarding the issue of multiple tools is to work towards helping the *integration of existing tools during the enactment*, rather than creating more and more tools that teachers would have to learn. In this regard, reviewing tool integrators such as VLEs, and how they can be applied to computer-integrated classrooms can prove very interesting, looking for ways in which teachers can orchestrate more effectively the tools inside the framework of the VLE. This is an aspect that has not been looked at in this document, but it deserves deeper attention in the future.

Chapter 6

Conclusions and future work

Thus, we reach the end of this journey in search of better ways to explain (and to implement) teacher enactment of CSCL in computer-integrated classrooms. If the kind reader has arrived here after wading through the 80+ pages of report that precede this, he (or she) deserves a short and to-the-point conclusion before wrapping up and heading somewhere else...

6.1 Conclusions

But first, let us remember what has been said so far in this report: the work presented here accounts for the first year of the author's research on the topic of *teacher enactment of computer-supported collaborative learning (CSCL) activities in computer-integrated classrooms* (CiC), paying special attention to the phenomena of flexibility and orchestration, and with the aim of designing CSCL tools that support teachers in the everyday practice of this enactment. Furthermore, design-based research was proposed as a suitable methodology for this overarching research effort.

In this document we have reviewed past educational research *literature* in search of a *model* on how (and why) teachers enact their classes the way they do, and we have found that the interactions of a number of *intrinsic aspects* of teachers (their knowledge, goals, beliefs and emotional attitudes) with the concrete *context* of each classroom is what shapes the teacher's practice when designing and enacting activities. Moreover, we have also defined what kind of setting a *computer-integrated classroom* is, and how new technologies get *integrated* into the classroom. We discovered that the classroom can be viewed as a complex *ecosystem*, in which computer uses might thrive or die. Also, we found that *intrinsic characteristics of teachers* are also an important factor in this integration, apart from the obvious availability of digital resources, their maintenance and adequate training. We have also reviewed some of the main problems that teachers face when enacting CSCL activities, finding that *orchestration* of activities,

groups and tools is one of the main processes in CSCL enactment, and that emergent situations that happen in the course of everyday teaching practice require a certain amount of *flexibility* from the tools, so that teachers are able to improvise. We also noticed that most improvisation is *pattern-based*, and thus, that improvisational enactment could be seen as a mixing and matching of patterns in real time.

Furthermore, we have examined the concept of *affordances* in CSCL tools, and we have analyzed one example application, GroupScribbles, from the standpoint of its affordances for enactment and the other concepts reviewed in the document. This analysis uncovered interesting features of the application: that its affordances made it suitable for the accomplishment of certain educational goals, and also that they made it suitable for improvisational forms of teaching (e.g. by fusioning design and enactment through the use of a few simple metaphors that could be rearranged in real time).

Afterwards, we have summarized the *field experiences* that took place at a real primary school setting in Cigales (Spain) for the past six months, as a pilot study on our design-based research effort to study teacher enactment of face-to-face CSCL activities. This study helped us to understand many aspects of the *context* and intrinsic factors of teachers at the school, even if few occurrences of improvisation or collaborative learning were observed.

And finally, we have tried to bring all these findings together into a *conceptual framework* that includes the relationships between all the aforementioned notions, in an effort to explain teacher enactment of CSCL activities, and as a guide in our design of supportive CSCL tools. With this conceptual framework in mind, we have formulated a number of *recommendations* that CSCL tool designers should have in mind when constructing CSCL environments to support teacher enactment in the face of emergent situations.

Even if this research work (and specially the aformentioned field study) was set about to uncover the elusive nature of teacher improvisation with technology, we found ourselves at the end of this year with surprisingly *few things to say about improvisation*. One could conclude that this was due to an inadequate research design in order to study improvisation, but we would rather think that the small amount of improvisation observed and the opinions expressed by teachers at the school indicate that maybe our initial question was not the most relevant. Regardless of the importance of improvisation for our current research, this has also taught us the importance of being *open to changes* (specially in the first stages of any research effort), and the advantages of working in authentic contexts from very early on, which can help the researcher in avoiding unanticipated caveats and searching for problems that simply "are not there".

One of the main conclusions that we can draw from our study of *flex-*

ibility is that, if teachers are meant to react to unexpected occurrences (or enact contingent plans) during enactment, they must *know the script* they are following, its *goals* and how each part contributes to those goals. Furthermore, the implementation of the *task flow* of the activity (either socially-managed or technology-managed) must be *flexible* enough to allow for changes, including also group formation and tool assignment. Even if these changes could be automated by the system, the amount of information that is exchanged outside the technological means of the classroom hints towards *teacher-initiated activity adaptations* (although the teacher's perception can be enhanced by technological means, such as advice based on interaction analysis). The discovery and application of *improvisational patterns* has been proposed as a means of informing the design of flexible CSCL tools and to help in the professional development of teachers.

Regarding *orchestration*, we can draw somewhat less concrete conclusions: as it occurs with enactment in general, *orchestration can be designed* (e.g. through the use of macro scripts to structure the orchestration, although it can also be done through normal spoken discourse), but it also *has to be performed in real time*. This again points towards the flexibility on the assignment of tools and groups during the runtime of an activity (to cope with unanticipated events), and to the importance of teachers knowing which tool best matches the educational goals that operate at every moment.

Another important lesson that has emerged from this year's work is the crucial role that the concrete *context* of the research plays in any research of this kind. Away from the laboratory, the restrictions imposed by working in a real school, with real teachers and students in their everyday activities, working inside the framework of a concrete curriculum, forces a very different point of view from the researcher, as compared to working in the lab. Context can make or break a research, and working with context in mind can be specially important for the *sustainability* of the research efforts after the researchers and/or their funding are gone.

In order to have this context in mind, we have proposed a first *extended teacher model*, in order to explain enactment of teachers and know which factors should be taken into account when designing enactments in an educational setting. The model is still not proven or complete, and it should be made more concrete in its implications for each one of our foci of interest (mostly, flexibility and orchestration). However, significative advances have been made and we can now draw our (incomplete) model for the teachers in Cigales, as it can be seen in figure 6.1.

As it can be seen in the figure, the primary school in Cigales has some *disadvantages* (e.g. the low technical or collaborative knowledge of teachers, the lack of time for extensive training and activity design), which are not necessarily distinctive from those of other schools, but should be kept in mind for future interventions. Yet, this setting also shows several traits (e.g. the openness of the school to research projects, the availability of

Context

Constraints

Abundant ICT resources

Voluntaristic school culture

Lack of time

Open to research projects

Rural school

Heterogeneous ICT resources

Goals
Teaching how to live and socialize

Knowledge
Low in pedagogical uses of ICT
Basic technical expertise
Low in collaborative techniques
Varied teaching expertise

Teacher

Beliefs
Technology takes too much time to prepare
Technology as motivator
Technology allows storing and refining
Technology should be taught
Technology is unreliable
Small improvisations are necessary
Improvisation is unprofessional
Collaboration is difficult for children

Emotional
Technophobia

Teacher practice

Design
Design patterns
Uniform design workflow
Adaptation of tasks to students
Careful grouping

Enactment
Low levels of collaboration
Limited tool orchestration
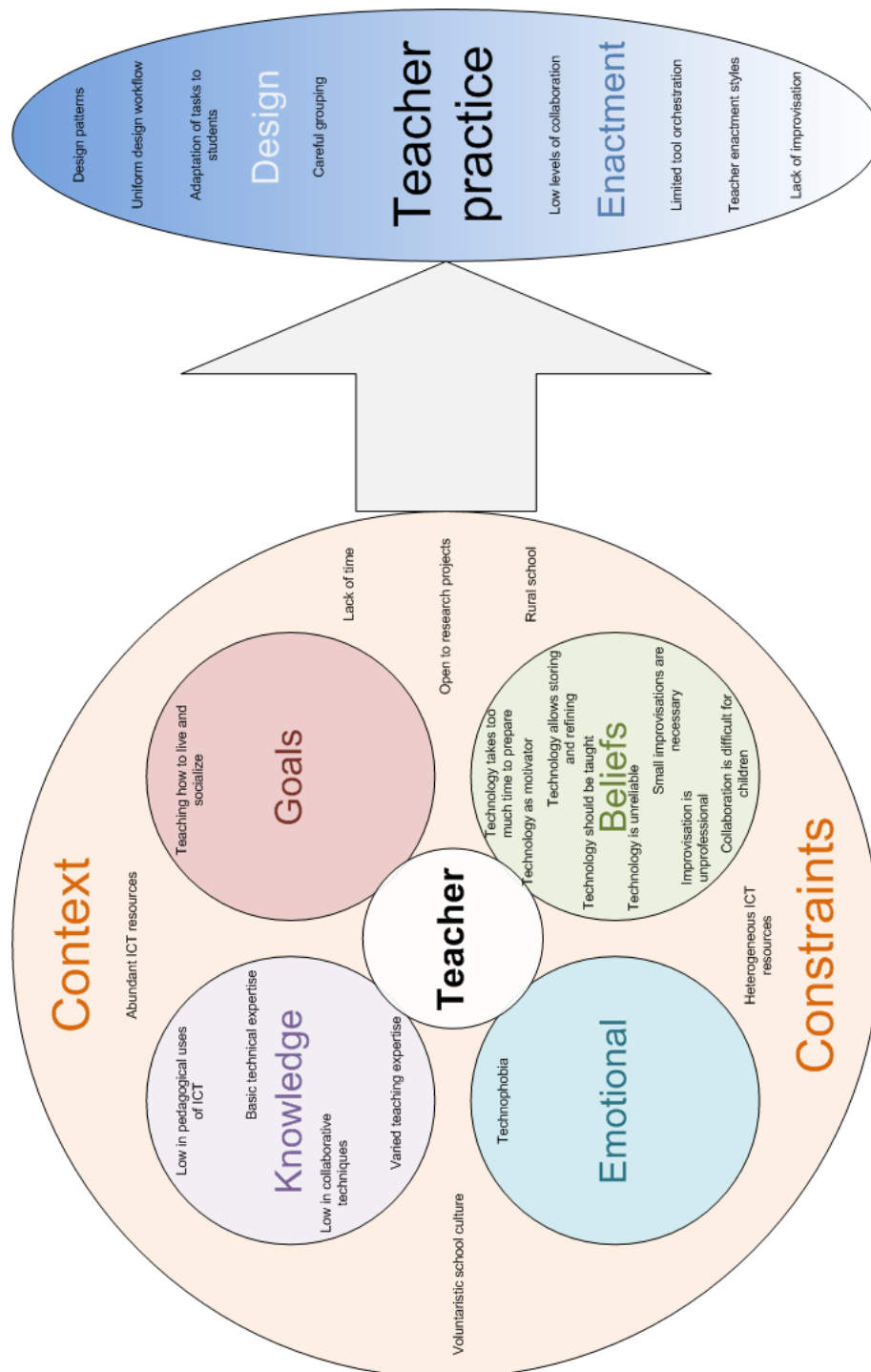Teacher enactment styles
Lack of improvisation

Figure 6.1: An (incomplete) Cigales school teacher model

ICT resources, the voluntaristic school culture) that make the school a very promising scenario for future inquiries.

The experiences in Cigales with the *GroupScribbles* tool proved to be quite successful, in the sense that teachers and students perceived it as an adequate tool for their level and their context, even if teachers could suggest a number of minor changes (e.g. the translation of the application to Spanish, or a few usability enhancements). The largely homogeneous usage patterns of teachers point towards the validity of the tool for *certain kinds of activities* (which could be linked to the *affordances* of the tool). However, the discovery of new design patterns not documented by the tool's creators also hints at the unexpected *creativity of teachers*, an ability that maybe would have not manifested in the case of a more restrictive tool.

Even if the tool was deemed to be adequate, we can also conclude that adequate tools (e.g. flexible tools, if flexibility is our goal) are not enough to elicit the desired behavior. While *being able* to act flexibly is important, knowing *how* and *why* to be flexible, and *wanting* to do so are at least as important. Thus, *enactment patterns* (be them either improvisational patterns, orchestration patterns, etc) must be internalized to some extent by teachers, before they can act flexibly.

In fact, another rather striking conclusion of this report, performed by a technologist with technological tools in mind, is the importance of *teacher knowledge* (and how teachers should be taught) in order to use the tools in an effective way. Basic technical knowledge is a *sine qua non* condition for usage of tools, but so it is the *pedagogical application of the tools*. Unfortunately, this is an often neglected aspect in any training program for teachers, partly because the topic has not been so well researched. Yet, we believe that learning something (e.g. to use a tool) in the context where that skill is going to be used (e.g. teaching) is the only way to achieve enough expertise so as to be able to intuitively improvise with it.

Finally, we should not close these conclusions without summarizing the recommendations for CSCL tool design that have been distilled during this year's research work. Any tool designer intending to help teachers in the enactment of CSCL activities (and, specially, in face-to-face settings such as computer-integrated classrooms) should consider:

- Taking into account the *intrinsic factors of teachers* (knowledge, goals, beliefs, emotions): concrete ones if available, general ones if aiming at a wider audience.

- Looking for compatibility (or even better, synergies) with *existing tools* in the classroom.

- Uncovering and exploiting *improvisation patterns* in enactment, either by observing teachers or by deconstructing learning design scripts.

- Allowing for *mixing and matching* of these patterns in real-time.

- Fusioning *design and enactment*: enactment *is* design. Make design fast and easy.

- Finding *orchestration patterns* and exploiting them. Match tool affordances to educational goals.

- Consider the *context*, including student level: is the tool adequate for them?

6.2 Future work

Regarding the *next steps* in this research about teacher enactment in computer-integrated classrooms, some general suggestions have already been made in chapter 5, but here we will list some of the clearest milestones that we foresee in our voyage:

- Even if this report contains a large amount of *literature* and theoretical review, still many fields have not been properly looked at, and knowledge about several topics will be needed in order to successfully plan future studies and interventions. Some of these topics include:

  - Application of design-based research (DBR) to the field of CSCL, both through theoretical readings and exemplary literature.

  - Literature about patterns in general, and learning design patterns in particular, in order to better define what a pattern is and what it should look like.

  - Teacher training in collaborative and CSCL techniques, paying special attention to the issue of sustainability of our efforts, and benefitting others from the knowledge generated in this context. For example, informal learning methods could be looked into for our training programs, and in order to disseminate the knowledge gained in our research.

  - Literature describing CSCL scripts and techniques, specially techniques that are appropriate for students in primary school. This is an issue that has not been tackled in this document, but we cannot expect that the same scripts will be equally useful for students at so disparate disparate as primary school and university.

- Conversations should be held, as soon as possible, with the teachers in Cigales, in order to agree and prepare our cooperation for the next academic year. Special attention should be put in discovering which are their educational goals, at different levels of granularity, both within and without the curriculum.

- With all this information, we should design our next round of design-based research, including:

  - Defining how many and which teachers are going to be target for our study in the next round of research.
  - Defining which aspects of the Cigales setting we want to modify, either external context factors or intrinsic factors of teachers.
  - Designing the teacher development program and the learning materials that will be used in it.
  - Continue observing Cigales teachers in different kinds of lessons, e.g. to compare how each of the tools really affect enactment, to uncover any improvisation or orchestration patterns that may emerge, etc.
  - Co-designing student activities with teachers, possibly including pen and paper activities, activities with GroupScribbles and also with other tools (e.g. with wikis).

- Another urgent action in our agenda should be to perform the necessary modifications in the GroupScribbles software, before any other experience takes place, so that any results gathered are not tainted by the language and usability issues that we observed in our preliminary fieldwork.

- Contacts should be made with the Singapore research team, since they have devised teacher development programs focusing on collaborative techniques and lightweight tools, and thus their help and advice can prove invaluable in the design of our own interventions with Cigales teachers.

- Contacts with the SRI should also continue, not only as the creators of GroupScribbles (in case any modifications to the tool are made), but also regarding their very interesting Contingent Pedagogies project. The study of contingency in teacher planning complements very well some of the notions presented in this document.

- In parallel with these actions towards the implementation of the design-based research effort, we should not forget about the more theoretical side of the study. This includes the aforementioned literature reviews, but also a *deeper study of the resources and tools* that are available in the classroom. As it has been suggested, an affordance analysis and mapping with teachers' educational goals could be the first step in this direction.

- In the same theoretical direction, an analysis of the relationships between the concepts presented here and existing research at the GSIC-

EMIC group on CSCL activity design patterns (and, specially, CLFPs[1]) would be very much needed, and could potentially uncover some first improvisational patterns that could be put to test in our field experiences.

- Finally, we should not forget the relationship of this work with other efforts in the same research group, specially the one involving the integration of CSCL tools into the framework of virtual learning environments (VLEs). A deeper analysis of how the concept of pattern-based flexibility should be applied to VLEs is needed, but we believe that the addition of methods or tools for more flexible enactment in any VLE would be a very desirable breakthrough in computer-supported collaborative learning.

In this document we have tried to clarify and understand a problem that we think is currently important, and will gain importance with time, if educational policies continue the way they currently are: the gap between the technical means for education that we devise, which change very rapidly, and the not-so-fast-changing minds of its main users in the classroom: teachers. Children and other students may have the mental plasticity to cope with anything we throw at them, but teachers can have a harder time in bridging this gap. If this report helped in acknowledging the deepness of this gap, and helps in keeping that gap in mind the next time a CSCL tool to be used in schools is designed, this humble author will be very much honored. If not, at least let us hope that you have a table with a 3-centimeter-shorter leg.

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