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Recurrent routines: Analyzing and supporting orchestration in technology-enhanced primary classrooms

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ABSTRACT

The increasing presence of multiple Information and Communication Technologies (ICT) in the classroom does not guarantee an improvement of the learning experiences of students, unless it is also accompanied by pedagogically effective orchestration of those technologies. In order to help teachers in this endeavour, it can be useful to understand how this orchestration takes place in real-world classrooms, and to provide teachers with professional development opportunities that can be easily applied to their everyday classroom practice. This paper describes a qualitative field study conducted in five primary school classrooms where a new collaborative software was introduced alongside existing classroom technology. For six months, teachers designed and orchestrated classroom activities in these authentic, technologically-rich settings. The analysis of the resulting activity designs and enactments uncovered a limited set of recurrent elements of teacher practice, or routines. These routines and their graphical representation are posited as a useful analysis tool for researchers in understanding complex teacher practices with ICT. Moreover, the authors propose that these routines offer new opportunities for professional development of teachers in effectively using ICT in their classrooms. Initial uses of these routines in teacher workshops, with encouraging results, are also presented.

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1. Introduction

Information and Communication Technologies (ICT) are being introduced increasingly in classrooms all over the world (see Galanouli, Murphy, and Gardner (2004) and One Laptop Per Child Initiative (2009) for examples in primary and secondary education). However, the introduction of a new technology alone does not guarantee improved learning experiences, or greater learning outcomes. Over and over again, we have seen how ICT, in their different incarnations, are applied to education in a way that only leads to technology underusage and mimicry of the uses of older technologies (see Hoppe, Baloian, & Zhao (1993), Cuban (2001), Watson (2006) and Hermans, Tondeur, Van Braak, and Valcke (2008)). Even though research projects that consider both pedagogy and the development of technical skills in tandem do exist (Beyond Current Horizon Project, 2010; Mishra & Koehler, 2006; Shechtman & Knudsen, 2009), most current examples of professional development programs for teachers concentrate mainly on the technical capabilities of these new tools, divorced from actual teaching practice (Jung, 2005).

Teachers trying to enact learning activities in one of these technology-enhanced classrooms, will have to coordinate the different tasks that are to be performed using the variety of available technologies, be they ICT (networked computers, digital whiteboards, etc.) or not (pen and paper, blackboards, books, and the like). This coordination is made even more complex in the case of teachers trying to apply collaborative learning techniques to their classrooms (i.e. computer-supported collaborative learning or CSCL, see Koschmann (1996) and Dillenbourg, J rvel , & Fischer (2009)), since the activities will be spread over several social levels (individual work, small-group work or whole-class activities). Fischer and Dillenbourg (2006) have referred to this coordination of different activities performed with a variety of tools, occurring at different social levels and even across different contexts, as "orchestrating learning".

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Although the metaphor of orchestration has a long history in educational literature, there is a dearth of studies on how the orchestration of multiple ICT tools is performed by practitioners, since most studies concentrate on the use of only one tool (see, for example, [Beauchamp, Kennewell, Tanner, & Jones, 2010](#)). Given the lack of useful conceptual models or frameworks on how this orchestration is done by teachers, we have employed inductive (bottom-up) research methods ([Barab & Squire, 2004](#); [Glaser & Strauss, 1967](#)) in order to propose a conceptual framework that may guide further studies and interventions. This article presents the results of a long-term research effort towards understanding the orchestration phenomenon in an authentic setting, and proposes an initial framework of how teachers design their lessons and enact them using multiple tools.

With these aims in mind, the authors have conducted a qualitative field study in five classrooms of a primary school in Spain, with students ranging from 6 to 8 years old. For six months, a board-based collaborative learning tool that provides a means by which students can share ideas on screen (Group Scribbles, see [SRI \(2008\)](#)), was introduced in their classrooms, where other ICT tools (e.g. networked desktop and tablet PCs, digital whiteboards) were already present. During that time, the authors observed and shared experiences with teachers as they designed and enacted activities combining all those elements in an authentic educational context (i.e. these activities were integrated with the usual curriculum and schedule).

By analyzing the designs of the activities and their enacted counterparts, a limited number of recurrent activity patterns, or routines, were uncovered. The translation of abstract activity designs into concrete classroom enactments, and even the improvisation of parts of the activities due to unexpected occurrences, were structured around creative combinations of these routines. We posit that these recurrent routines and their graphical representation provide a valuable analysis tool for researchers in order to understand how teachers coordinate complex activities involving multiple tools, tasks and social levels. Moreover, initial experiences with teachers show that these routines (categorized by the kind of task where they usually appear) can be used to support teachers in orchestrating such complex settings.

In the next section, we provide an overview of the problem of orchestration, and the role that recurrent, reusable solutions (also known as patterns) can play in complex practices such as this orchestration of learning processes. Section 3 describes the context and methodologies used in our study, while Section 4 exemplifies the analysis of the enacted activities, their graphical representation and the routines uncovered through that analysis. Afterwards, first evidence of the usefulness of the routines in supporting teacher design and enactment are described in Section 5. Section 6 discusses the main implications of this contribution, counterpointing it with related work in the literature. We finish the document with a number of closing remarks and an overview of current and future steps in our research concerning the elicitation and usefulness of these routines to support teacher orchestration of technology-enhanced classroom activities.

2. The role of patterns in orchestrating learning

As digital technologies become more and more pervasive in education at all levels, ICT tools are becoming a commodity that coexists with other legacy tools (e.g. pen and paper, books, or traditional blackboards). Thus, classrooms are becoming a complex ecosystem of technologies and tools that can be used and combined in many ways to support learning processes of students ([Zhao & Frank, 2003](#)). On a parallel trend, pedagogical research has long been advocating for methods and practices that are more complex than the unidirectional flow of information typical in traditional lectures (see, for example, [Bruce \(2008\)](#) and [Jorrín-Abellán and Stake \(2009\)](#)).

The acknowledgement of these increasing levels of complexity in learning activities has given birth, in the past few years, to the usage of the metaphor of orchestration. The term “orchestrating learning” has appeared in several fields related to the usage of ICT in learning, such as Computer-Supported Collaborative Learning (CSCL, see [Koschmann, 1996](#); [Dillenbourg et al., 2009](#)) and Technology-Enhanced Learning (TEL, see [Balacheff, Ludvigsen, de Jong, Lazonder, & Barnes, 2009](#)). [Fischer and Dillenbourg \(2006\)](#) defined orchestration as “the process of productively coordinating supportive interventions across multiple learning activities occurring at multiple social levels”. However, the usefulness of this metaphor remains to be proved and, to the best of our knowledge, no global, systematic view of it has been posited yet.

As we have seen, the enactment of activities (and especially collaborative learning activities) in a technologically-enriched classroom is a very complex process that has to take into account a multitude of contextual, technical and pedagogical factors (thus the metaphor of orchestration). One way of dealing with complex activities (especially for non-expert practitioners) is through the usage of patterns. Design patterns were proposed by [Alexander, Ishikawa, and Silverstein \(1977\)](#) in the field of architecture, as a way of representing successful solutions to recurrent problems in a field of practice (in Alexander's case, architectural design). The basic idea of design patterns is to present a recurrent problem that appears in a field of practice, and to describe the core of a successful solution to that problem, in a way that allows it to be reused throughout different contexts.

This approach provides several advantages for practitioners (especially non-expert ones): first, its problem-orientedness allows for easy location of solutions when the practitioner faces a problem; second, it allows practitioners to be more productive, as they are free to concentrate in the creative solution of unsolved problems (to which no patterns already exist). Design patterns also have the goal of making expert knowledge available to non-experts (in this case, teachers who are not experts in the pedagogical uses of ICT), as well as to serve as a tool for communication among practitioners in a field. Patterns have been successfully applied to fields as disparate as software development ([Gamma, Helm, Johnson, & Vlissides, 1995](#)) or the design of CSCL activities ([Hernández-Leo, Villasclaras-Fernández, Asensio-Pérez, & Dimitriadis, 2009](#)).

In this document we follow a variant of the design patterns approach to try to make a complex activity (the enactment of technology-enhanced, collaborative learning activities) available and understandable for non-expert practitioners, in the form of what we have called *routines*.¹ Taking into account the known properties of design patterns, we hypothesized that teachers would be able to easily find solutions to recurrent problems in the orchestration of activities. Also, that a pattern approach would allow teachers to apply and combine these core solutions to lower-level problems when enacting activities with ICT, allowing them to concentrate on higher-order issues, such as creating an atmosphere of productive discussion and a sense of agency in the process of learning ([Mercer & Littleton, 2007](#)). These social and motivational aspects of the activities are emergent and largely contextual, and normally cannot be predicted in the design phase of an

¹ We chose the term “routines” instead of “patterns” for coherence with previous similar work (see [DeBarger et al. \(2011\)](#)), and due to the fact that these routines do not follow Alexandrian conventions and formalisms for patterns.

activity. Indeed, these latter aspects can very often be neglected as a result of teachers having to solve the myriad of minute technical and management problems that appear when ICT is present in learning activities.

To the best of our knowledge, patterns have only recently been applied to the area of teacher enactment with ICT tools (DeBarger, Penuel, Harris, & Schank (2011)). However, the concept of patterns is not completely unknown in performance-like practices (and we consider teachers' activity enactment as such, see Whalen, Whalen, and Henderson (2002) and Humphreys and Hyland (2002)). Borko and Livingston (1989) and Sudnow (1993) establish patterns as a basis for improvisational conduct in teaching and, more recently, studies by Beauchamp et al. (2010) examine how musical metaphors such as orchestration and jazz improvisation can illuminate our understanding of the patterns inherent in classroom behaviours. Also, in a related but different area, the design patterns approach was taken by Hernández-Leo et al. (2009) to support teachers in the design of CSCL scripted activities (especially practitioners not expert in CSCL design).

3. Context and methodologies of the study

In this paper, the authors address two main research questions: "how do teachers design and enact (i.e. orchestrate) activities with ICT tools (especially collaborative ones)?" and "how can we help them in doing so?". The lack of research studies and conceptual frameworks that address the phenomenon of orchestrating multiple ICT tools in the design and enactment of learning activities has prompted us to follow an inductive research approach, trying to derive "humble theories" from field data (Barab & Squire, 2004; Glaser & Strauss, 1967). In our attempt to understand in depth the first of the research questions, a qualitative case study (Stake, 2005, 2010) was carried out in the educational setting of a primary school in Spain. In order to propose a conceptual framework that helps us in answering to the second question, an analysis of the data collected during the case study was performed, and the concept of routines to structure orchestration has been put forward. This section describes the methodologies and the educational context of the case study, so that the reader can understand where, how and why the data was gathered. The analysis and the resulting conceptual framework for analyzing and supporting teacher orchestration are presented in the next section.

One of the main characteristics of qualitative research studies is its focus, not on the statistical significance and generalizability of the data collected, but rather on maximizing the understanding of the complex factors and relationships that shape the case under study. Even if the case study itself is not the main focus of the paper (please refer to Prieto (2009) for a more complete account of the study), its role as the main source of data makes it important to understand its context, as well as to explain the reasons behind the choices that researchers made during the study.

Several elements are crucial in the understanding of the case study's method and conceptual structure (Stake, 2005): the choice of the educational context and the sources of information (mini cases) that would conform the study; the choice of technologies that the study would concentrate upon; the data gathering moments and techniques employed in the study; and finally, the evolution of the tensions around which the case study unfolded (issues). In the following paragraphs, we describe these elements and the ways in which they were employed in the study. Furthermore, these elements and choices have been represented graphically in Fig. 1, following the model from Stake (2005).

3.1. Choice of context and mini cases

With the aim of gathering evidence about the main research question of the study (how teachers orchestrate activities with collaborative ICT tools), a number of teachers would be observed while designing and enacting classes in their everyday context (i.e. a school). The context chosen for conducting our study was a primary school in a rural setting nearby Valladolid, in Spain. This school, despite being publicly funded and being in a rural environment, was equipped with a considerable amount of technological resources: digital whiteboards in all classrooms, three portable sets of 20 tablet PCs, two ICT classrooms equipped with 20 PCs each, etc. However, what makes this school noteworthy is that both its educational community and, especially, the school principal, have been developing a long-term project with the aim of integrating technology within the curriculum, as well as promoting the virtual communication and sharing of resources within the educational community.

In order to develop this project, the school principal has the leadership in performing non-compulsory training sessions of 2 h for all the teachers, every two weeks during the academic year. The first sessions are usually focused in training teachers in the use of the myriad of ICT resources already existing in the classrooms (e.g. to learn how to use the Moodle platform or the digital whiteboard software). As the academic year progresses, these sessions become more oriented towards didactic uses of ICT (e.g. making a presentation of the water cycle using digital whiteboard software, or making an online survey to assess the students' knowledge about one specific curriculum content).

In general, school policy and culture have been heavily influenced by the school principals holding this position during the last decade, as well as a core team of permanent teachers. Thus, the school has been involved in several innovation projects funded by the regional and national governments, or through direct collaboration with educational technology companies and university departments. Therefore, the school culture and leadership can be considered innovative and open to change. This unusual attitude towards innovation and technology is counter-balanced by features common to many schools in Spain, such as the great need of teacher training in ICT and the high annual turnover of the staff (around 30–40 per cent of the teachers are renewed every year). This balance made us think that the school would be a good context for our efforts in supporting and providing help to non-ICT-expert teachers in the orchestration of technology-enriched classrooms.

Although this scenario provided a good starting point due to the abundance of hardware, it is well known that schools need something more than investments in technological resources. The current Spanish schooling system calls for didactic and methodological changes to better implement the educational capabilities of ICT. In this sense the school principal explained:

W: When we started to give special attention to technology as a useful resource in the school, we already knew the goal: all classrooms should be well equipped. Now, we face another challenge: to do really different things with these technologies. The most difficult aspect is the methodological change. It would be useless if we have spent so much money just to repeat with the Internet and the computers what we did with a pencil and a piece of paper. School Principal Interview. 1st April, 2009.

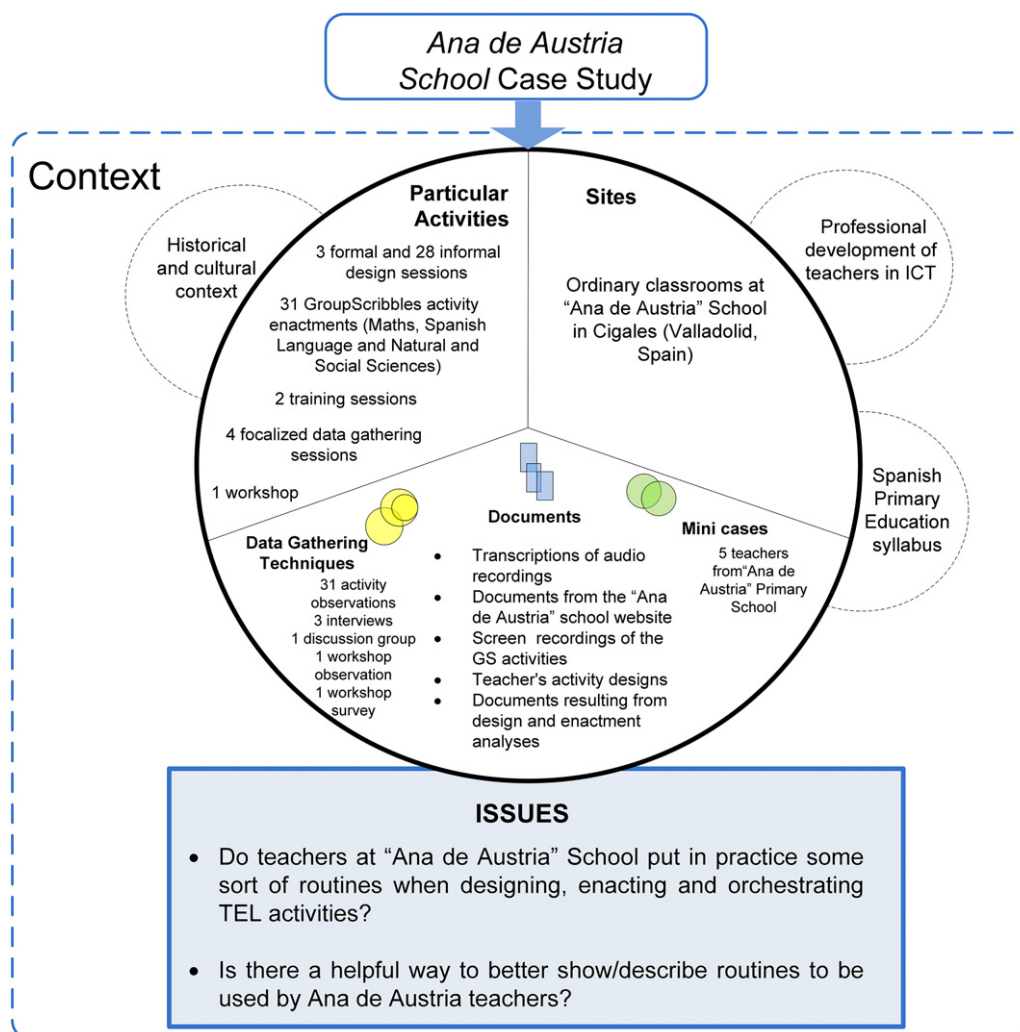


Fig. 1. Conceptual structure of the case study, following the schema proposed by Stake (2005).

A case study is always a matter of contention, since a researcher always has to choose and select the contexts, informants and situations to be studied. Given the size and complexity of the school (in this case, with more than forty teachers and hundreds of students enrolled), qualitative case studies normally focus on a limited number of sources of information (e.g. a number of teachers) that exemplify the tensions and issues of the case, which are often called "mini cases". We spent 6 months closely working with eight teachers from the school, five of them being general teachers (working with 6–8 year-old students) and two specialists, one in English as a foreign language, as well as a special needs teacher. Also, the principal of the school participated in his role as a general teacher. Out of these eight teachers, we chose four of the general teachers and the principal. These five mini cases provided the most opportunities for observing interactions with multiple ICT, but at the same time they represented a varied spectrum of educational and ICT expertise: Three of them had more than 15 years of teaching experience, while the rest had less than eight years of experience. Furthermore, all of them, with the sole exception of the principal, had little pre-service training in pedagogical uses of ICT. As teachers themselves told us, they had not received specific training in the technical and pedagogical uses of ICT in education. Therefore, the ICT background of these teachers consisted mainly of basic knowledge of office software, acquired in several lifelong learning courses.

3.2. Choice of technologies

As it has been mentioned, in our study a number of teachers would be observed while designing and enacting classes in their everyday context, integrating the use of a collaborative educational software (Group Scribbles) in their daily practices. Group Scribbles is a simple collaborative software, created at SRI International and it is based on metaphors familiar to the teachers: public and private boards where ideas are shared, virtual adhesive stickers where students and teachers can draw and write, etc. (see Fig. 2). Group Scribbles was designed with face-to-face scenarios in mind, and it is especially well suited to be used in classrooms with an electronic whiteboard and tablet PCs. The election of this CSCL tool for our study was motivated by its affordances for flexibility and improvisation (Roschelle et al., 2007), and because of prior experiences with Group Scribbles by our own research group (Dimitriadis et al., 2007).

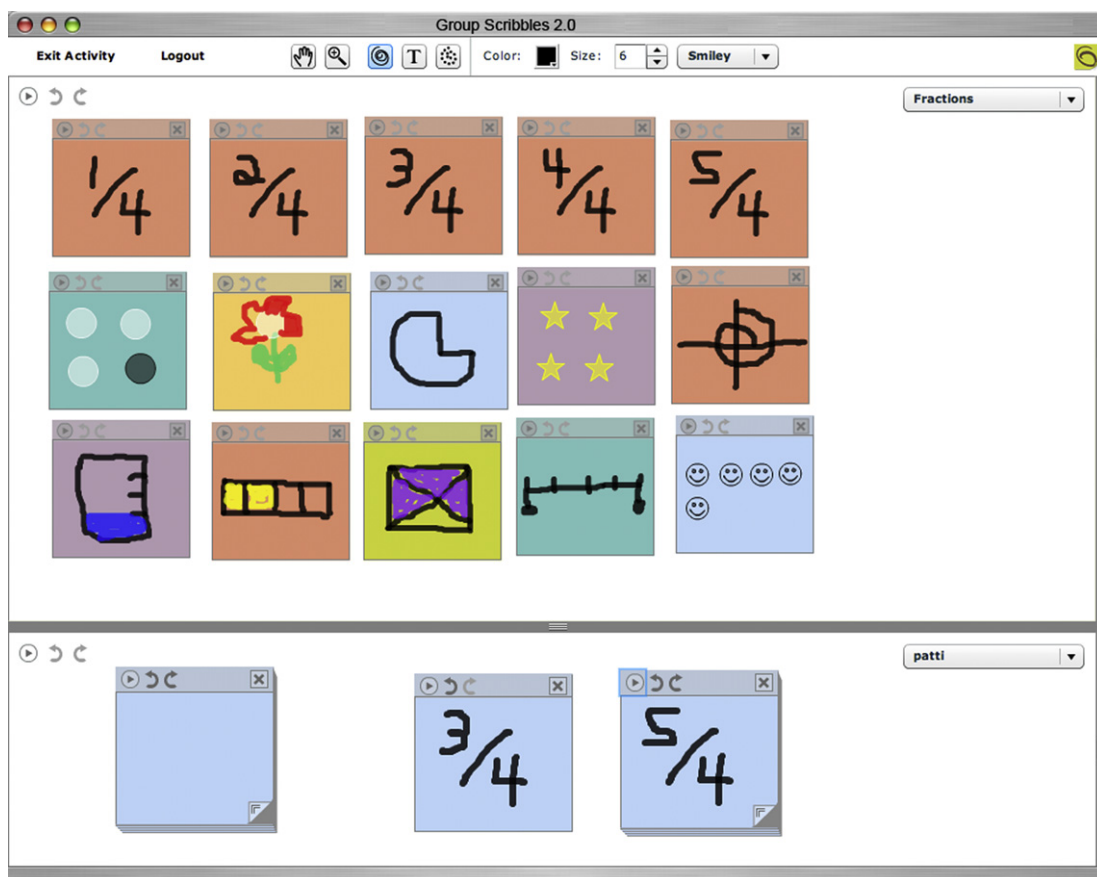


Fig. 2. Group Scribbles desktop appearance (SRI, 2008), showing public and private boards (upper and lower parts of the screen).

3.3. Particular activities and data gathering techniques

The activities and nature of the data gathering were agreed upon the initial contacts with the principal and the teachers. The following moments and data gathering techniques were defined:

- *Training sessions.* Two training sessions, of 2 h 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, focused on advanced uses of the tool and the design of more complex activities with Group Scribbles. We decided to provide few training sessions in order to observe what kind of activities and uses of Group Scribbles were put in practice by teachers in a natural way (instead of imposing our activity designs on them). The audio of these sessions, as well as the presenter's screen, were recorded.
- *Activity design support and analysis.* Three formal sessions of activity design took place, in which the researchers helped the teachers to transform their activity ideas into actual Group Scribbles activities. The need for this kind of sessions faded with time, as teachers progressively internalized what was (and was not) possible with the tool. Thus, the formal design sessions evolved into informal design conversations (as many as observed activities). Sixteen of these designs from different teachers were available in written form (extracted from the teachers' notebooks), and were analyzed in search for common design routines (see Section 4).
- *Activity enactment support and analysis.* It was agreed with the principal and the teachers that Group Scribbles would be used in at least one or two sessions per week, by the 5 participant K6–8 teachers. In order to collect data we carried out 31 participant observations of classroom enactments. Most of them were observed by two researchers, who took notes independently (for observer triangulation purposes). Each classroom had between 18 and 25 students of ages 6–8 (depending on the classroom and the day of observation). The sessions were audio recorded, with additional data coming from screen recordings of the teacher's computer. The data from sixteen of these enactments by different teachers were analyzed in search for common enactment routines (see Section 4).
- *Focussed data gathering and analysis.* With the aim of highlighting some of the aspects related to the school context and the teachers' knowledge, beliefs and practices with regard to ICT, three semi-structured interviews took place with the principal and two of the K6–8 teachers. Moreover, we also carried out a discussion group with the remaining teachers. The recordings of the interviews and discussion group were transcribed, and transcriptions were coded using open coding techniques, as a part of a qualitative research approach (i.e. analyzing the transcriptions line by line to identify substantive ideas emergent within the data, and grouping them into nodes and categories). Moreover, we used qualitative research software that helped us to manage, shape and make sense of this unstructured information (Richards, 1999).
- *Access to documental sources.* We also had access to a variety of information and documents about the resources, educational projects and activities of the school. This documentation was used to enrich the aforementioned focussed analysis.

3.4. Issues in the study

It is important to note that we approached this study as “progressive in-focus”, where the meanings, data gathering and prospective findings change throughout the study (Stake, 2010). In our case, we observed that teachers often used recurrent structures both in the design and the enactment of the activities (even when the teachers improvised sections of the lesson). Thus, over time we defined two “issues” (tensions used to force researchers’ attention to the complexity and contextuality of the problem) which would help us to understand our case study in depth: “Do teachers at our concrete school put in practice any sort of routines when designing, enacting and orchestrating TEL activities?”, and “is there a helpful way to better show/describe routines to be used by these teachers?”. The emergence of these issues during the case study prompted us to analyze and compare the teachers’ designs and enactments with each other, in search of common activity patterns.

4. Routines: analysing and representing teacher designs and enactments

Now that we have provided a general overview of the context and the case study that generated the data for our analysis, let us continue to the analysis of the data and the results that it garnered. The authors have analyzed the data gathered during the observation of activities, along with the written design of the activities. This analysis aimed at understanding what happened in the classroom during the enactment of the activity, which elements the teacher manipulated (such as tools or tasks at different social levels), and how these elements were orchestrated. Also, the differences between the designed activities and their enacted counterparts represented an important focus of the analysis, to understand the transformation of the designs into actual enactments. Given this emphasis on the differences between designed and enacted activities, the work presented in this paper will focus on 16 of the 31 observed activities, of which we have explicit designs in written form (see, for example, Fig. 3).

The activities were designed by teachers themselves, most often by scribbling notes in their notebooks, and later they were transformed into Group Scribbles activities with our help. This setting up of the activities using Group Scribbles was done in formal or informal activity design sessions (as mentioned in Section 3). From the remaining 15 sessions we do not have written designs, and they were set up in Group Scribbles directly from teachers’ conversations and ideas. Thus, these activities have not been analyzed and represented as exhaustively, although they have been used as additional evidence to support the detection and analysis of routines, and for triangulation purposes.

From the analysis and comparison of the designs, a set of recurrent activity patterns were uncovered. We have called these patterns *design routines* (Prieto et al., 2010). Examples of these design routines include “Brainstorming” (a task in which the participants contribute one or more ideas in response to a question or a theme), “Clues” (a way of task distribution among students, in which the tasks are associated to each participant by means of a small task or enigma, which leads to the corresponding participant) or “Where is on the image?” (a task in which participants contribute ideas, names or facts, placing them in a specific place in a presented image). The catalogue of uncovered design routines can be seen in Table 1, and the reader may also refer to Prieto et al. (2010) for a more complete account on how these routines structured the design (as well as the enactment) of the activities done with Group Scribbles.

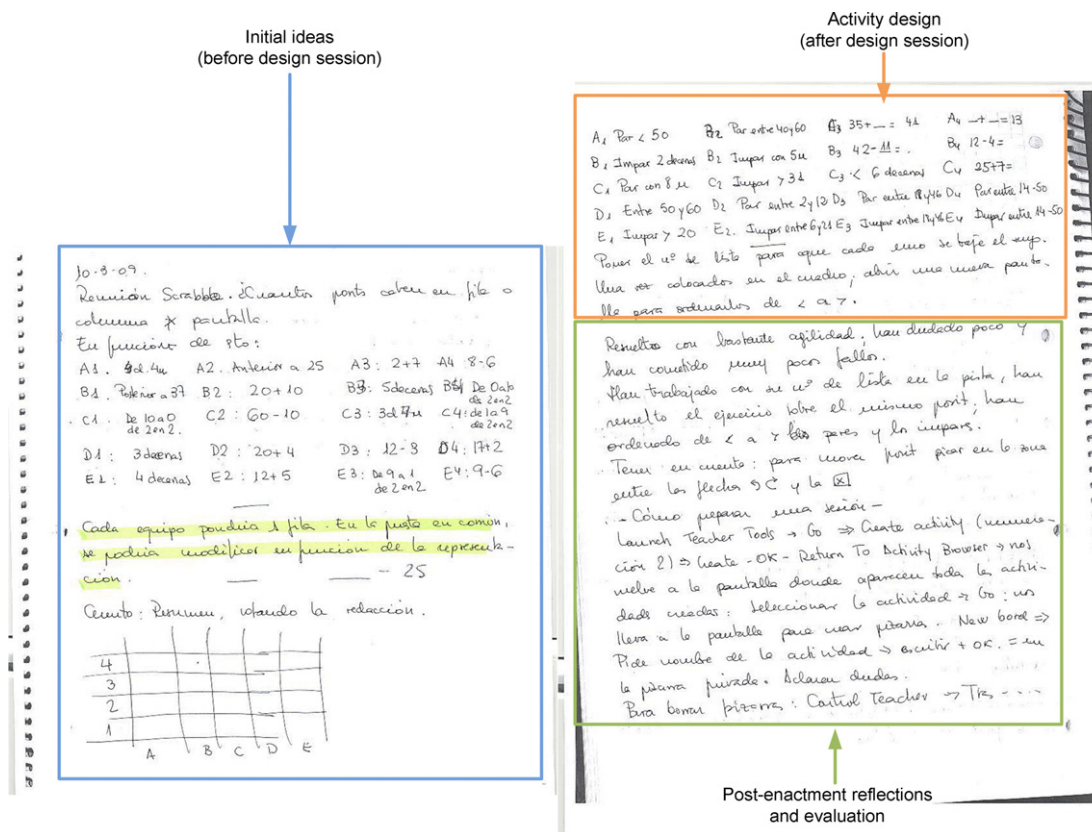


Fig. 3. An example activity design, taken from a teacher's notebook.

Table 1
Catalogue of design routines encountered in activities of the Cigales School (taken from Prieto et al., 2010).

Routines	Description	# appearances
Representing information/questions	Students generate questions or ideas related to a certain topic	22
Classification	Organize stickers in a public board, according to certain hierarchies or classification criteria	15
Distributed problem solving	Each student takes a sticker from the public board, representing a different task, solves it and puts it back to the public space	9
Clues	Each student chooses a task, by solving a riddle (e.g. the consonants presents in the student's name)	9
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
Poll	Students vote which, among a set of options, is their favorite (normally for later usage in the activity)	1
Pipeline	Each student takes a task from a public board, which represents a part of a bigger problem; after the student solves it, another student uses it for solving his/her sub-task, and so on	1
Self-task	Students choose which is the next task to be done	1
Where is on the image?	The teacher poses a question, and students answer by marking over a background image in the public board	1

In our study, teacher designs were rather abstract and high-level, many of them being just a few phrases scribbled in a notebook (Prieto et al., 2010). However, if we compare the designs with the actual enactment of those designs, we can see two main differences, which can be mapped to the modes of improvisation described in Kernfeld (1995) (as cited by Beauchamp et al. (2010)). On the one hand, additional tasks or phases were added to the design, completing it as teachers realized that the enactment would not work adequately without them (e.g. an evaluation of the results of a classification task was added, so that students got feedback on their knowledge). Also, another kind of completion took place as teachers improvised in the face of unexpected problems and opportunities that emerged in the classroom (e.g. performing an improvised task when all the designed tasks were completed faster than expected). These completion processes can be seen as “formulaic improvisation”. On the other hand, even for the tasks that were explicit in the design, a concretization took place, since there are several ways in which such high-level tasks can be performed (e.g. the evaluation of a task can be done directly by the teacher, or through supervised peer assessment, or on-the-fly vs. after the task etc.). This concretization process could be seen as “paraphrase improvisation”.

These parallel processes of completion of the task flow (parting from the abstract, incomplete design) and concretization of the performance, can then be compared with the ones in other activities, and recurrent elements begin to emerge. Continuing with the example of the assessment of a task, we observed that in many activities the teacher chose to perform the assessment verbally on her own, while in others the teacher chose a student and asked him/her to do the assessment using the digital whiteboard. These recurrent “ways of doing certain things with a certain purpose” is what we have termed *enactment routines*. Here, the emphasis is in the purpose of the routine, making it a problem-oriented structure, in the same way that design patterns in architecture represent the core of a solution to recurrent problems (Alexander et al., 1977).

Through this kind of analysis, 33 enactment routines have been derived. Examples of these routines include “Use the digital whiteboard to exemplify” (the teacher performs the actions expected from students with the digital whiteboard, so that they understand better the task at hand), “Correct your own mistakes” (when the assessment shows that a student response is not correct, the teacher asks the student to think again and produce a new correct response to be shared with the class), or “On-the-fly assessment” (while a task is being done by students, the teacher monitors the progress, assessing their knowledge and barging in if needed, to point the students in the right direction).

We can see that in this analysis, one of the main organizing factors is the tasks that are performed by the teacher and by students, and their distribution over time: each task can be seen as marking a definite phase in the flow of the activity. This conception of the task as the main organizing factor of teacher enactment can be traced back to the work of Doyle (1979). In the activities observed and analyzed, we can distinguish three main kinds of activities, from the point of view of the teacher:

- *Explanation tasks*, in which the teacher transmits knowledge to the students.
- *Support to task*, in which the teacher supports the work of students in a certain task.
- *Assessment tasks*, in which the results of the tasks are evaluated.

This classification does not intend to be exhaustive since, for example, the assessment of a task can be performed on-the-fly while supporting that very same task. Table 2 shows a partial catalogue² of these enactment routines, categorized along the kinds of task in which the routine normally appears. Thus, we can see that the “Correct your own mistakes” routine normally appears during assessment tasks, while “Use digital whiteboard to exemplify” appears while the teacher is doing explanations.

The design and enactment routines presented so far represent a useful way for researchers to codify teacher practices with ICT, and they also may be used by practitioners themselves to make explicit and share their knowledge about teaching practice. However, just stating that certain routines were used in an activity is not enough to understand what happened in the classroom. To further our understanding as researchers, as well as to help in communicating the enactments and the routines that were used, we have devised a graphical representation of the routine analyses that were performed on the activity enactments. This representation tries to convey the structure of the enactment, taking the metaphor of orchestration (and its definition as taken from Fischer and Dillenbourg (2006)) as a basis for the representation. Thus, the diagrams show the task flow of the activity (represented by a succession of design routines, and including the kind

² The complete catalogue of design and enactment routines can be downloaded from <http://gsic.tel.uva.es/%7Elprisan/20100718RoutineCatalog.zip> (Last visit: 12 Nov 2010).

Table 2
(Partial) Catalogue of enactment routines, classified by type of task.

Name	Short description	Task type
Correct your own mistakes	When an incorrect response is detected, the teacher asks the author to revise the response and put it back again in the public space	Assessment
Democratic reward assignment	The teacher helps the groups of students to reach a consensus about how many rewards should be assigned to each group, in light of their responses	Assessment
Discuss selected results	The teacher selects one or more of the student responses, to discuss with the whole class whether they are correct or not, and why	Assessment
Probe with false information	The teacher gives an incorrect response for a question or task, so as to see if the students detect the error, or they take the teacher's word for it	Assessment
Students detect mistakes	The teacher asks students to detect and manifest which proposed results are incorrect (as opposed to pointing them herself)	Assessment
Student revises the results in the whiteboard	The teacher asks one student to use the whiteboard to assess the responses, in front of the whole-class	Assessment
Disallow tool usage	The teacher impedes the usage of tools (e.g. by taking away the stylus of a Tablet PC, or disabling writing access in GroupScribbles), so that students pay attention to the assessment or explanation in progress	Assessment or Explanation
Heterogeneous group formation	Distribute students in small group work so that students with disparate characteristics (e.g. levels of knowledge about the subject matter) are put together	Explanation
Prepare backup materials	The teacher prepares additional (maybe identical) materials, in prevision of emergent problems (e.g. if some of the tasks are accidentally deleted)	Explanation
Rules of the game	The teacher explicits and emphasizes rules and routines to be enacted during the activity (e.g. the order of tablet PC usage, or the roles within each small group)	Explanation
Use digital whiteboard to exemplify	Using the digital whiteboard, the actions to be taken in a task are exemplified by the teacher, so that students can reproduce them later on	Explanation
Use graphics to support a task	The teacher uses drawings or images to represent the task or parts of it in a visual manner	Explanation
Calibrate task difficulty according to student level	The teacher assigns the different individual or small group tasks to each group, according to their knowledge level	Support/task
Disable idea copying	The teacher hides the public space until a task is ended, so that students do not copy the ideas from other students	Support/task
On-the-fly assessment	The teacher monitors the progress and barges in if needed, to point the students in the right direction	Support/task
On-the-fly peer assessment	In a dyad of students, one of the students performs the task while the other helps and/or regulates his partner. Then, the roles are reversed	Support/task
Use paper/tangibles to support a task	When performing an activity with ICT, the teacher also provides equivalent/complementary tangible materials (e.g. pen and paper), so that students can manipulate them physically	Support/task

of task of each of them: assessment, explanation or support to task), both for teachers and for students, as they traverse through different social levels (individual, group or whole-class work), the tools (ICT or not) that were used in the different phases of the activity and, finally, the enactment routines that mark how those elements were combined.

In order to further clarify these concepts and its representation, let us take a look at a concrete example: an activity enacted by one of the teachers, in a class with 18 students. This Math activity was enacted in one of the technologically-enhanced classrooms, which had a laptop and a digital whiteboard for the teacher and tablet PCs for the students, all running the Group Scribbles software. The students had to choose a task from a public board (a simple arithmetical operation, written on a virtual sticky note, alongside a coordinate, e.g. B1), solve it and put it back on another public board which depicted a grid with two axes (A, B, C... and 1, 2, 3, ...). Afterwards, students had to represent the numeric responses from the previous task in alternative ways (e.g. graphically), and put their responses in another public board. Fig. 4 shows images of the classroom and the completed activity as shown in the classroom digital whiteboard.

Fig. 5 shows the graphical representation of the routines from the design and enactment analysis performed on the aforementioned activity. In it we can see the different tasks that were performed by the teacher (at the top) and by the students (at the bottom). These tasks or phases can be of one of three kinds (explanation – stars, support/task – squares, and assessment – triangles), and they can also be assimilated to different design routines, as described in DeBarger et al. (2011) and Prieto et al. (2010). The tasks are also represented as being performed at one of three social levels: individual work, small-group work and whole-class work. Finally, enactment routines are grouped around each task, marking the moment in which they appeared.

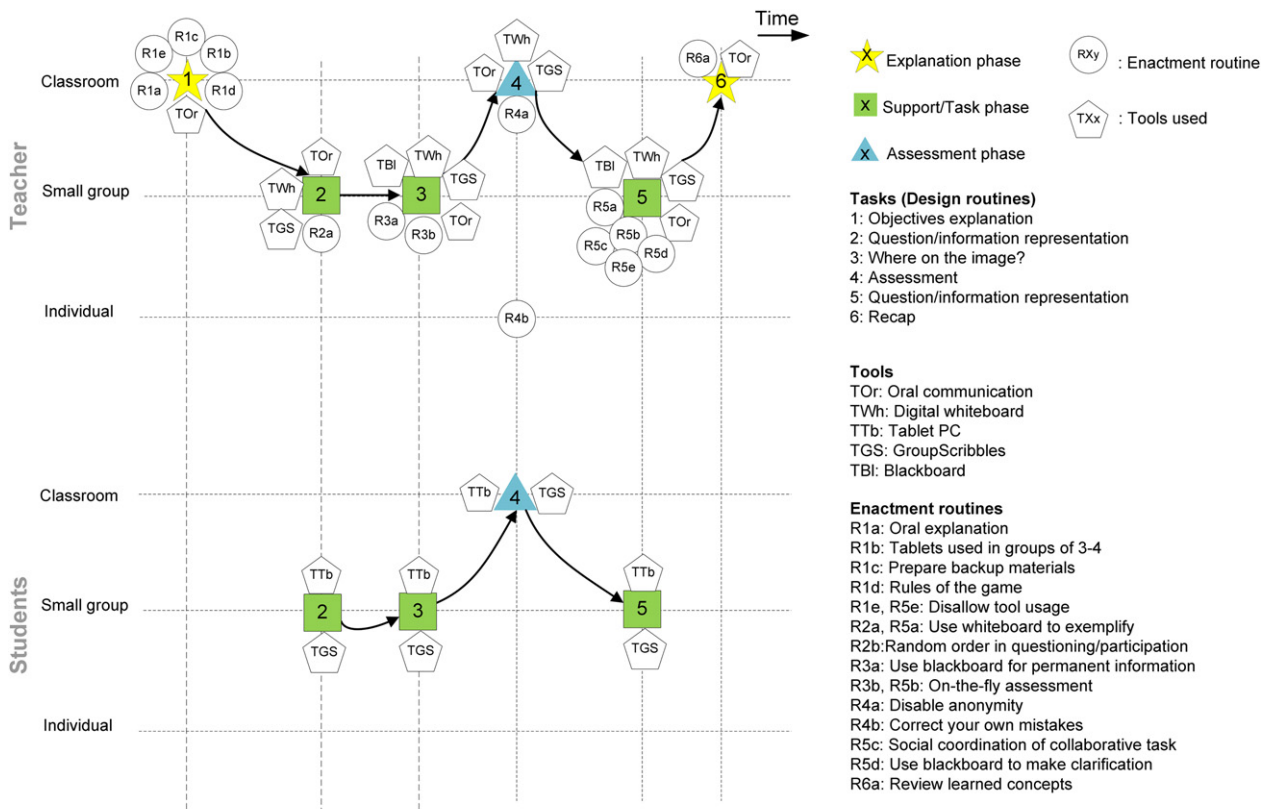
Thus, we can see how the activity design (as described in the previous paragraphs) was actually enacted: First, the teacher explained, orally, the goals and tasks that composed the activity (phase 1 in the figure), making groups of 3–4 students, and making strong emphasis on the rules to be enforced during the activity (routines associated to phase 1). Then, students had to solve the tasks assigned to them (phase 2) while the teacher used the whiteboard to exemplify and solve unclear aspects of the task (routine associated to phase 2). Afterwards, the students had to put their responses in the coordinates grid (phase 3), while the teacher assessed the results on the fly and used the blackboard to display the points for each team (routines associated to phase 3). On phase 4, the results were assessed orally with the help of the whiteboard and Group Scribbles, and students who had contributed incorrect answers were asked to correct their mistakes (routine associated to phase 4). Finally, as time was running out, the teacher proceeded to asking students to represent the numbers differently (phase 5), while assessing the results on the fly (routine associated to phase 5), and did a quick recap of the main concepts that had been mentioned during the activity (phase 6).

As we can see, this kind of representation provides detailed descriptions of complex teaching practices in one glance. Using these diagrams we can see, not only how activities are designed, but rather how those designs are turned into effective enactments (something a good design does not guarantee by itself). Also, frequent couplings of tools and tool uses (in the form of routines) can be extracted from such representations. Doing this for expert or successful activities could help in our understanding of which combinations of tools and tasks at different social levels are more successful than others.



Fig. 4. The classroom and the digital whiteboard during one of the analyzed activities.

So far, we have seen that teacher enactment in a technology-enhanced classroom is full of activity patterns, that we have called routines. But, as interesting as these routines may be to understand teacher practice for us researchers, the ultimate goal of this research effort is to support, to help teachers in their teaching practice with ICT. To that aim, the current set of routines has to be refined, selecting the most interesting ones, the ones that can be considered best practices in enacting teaching with ICT. This can be done by researchers and other experts (e.g. Meszaros and Doble (1997), p. 529), or by multidisciplinary teams of researchers and practitioners, using a workshop format (Winters & Mor, 2009). After this process of refinement, the set of routines would have evolved to a more problem-oriented set of elements, that can be assimilated to Alexandrian patterns. Then, those patterns should be made available to teachers, to assess their usefulness as a mediating tool in their practice with ICT. Now we will describe one possible way of completing this cycle, through workshops with teachers.



Routine: A specific way of doing things, having an educational goal in mind.

Fig. 5. Graphical representation of the design and enactment analysis of the example activity.

5. Making use of the routines: a first workshop with teachers

As a first step to study the usefulness of the design and enactment routines presented in the previous section, we carried out a 2-h workshop with teachers. Nine teachers from the school described in Section 3 participated in this workshop: four of them were part of the group of teachers that participated in the case study, four others were not part of the study, but had used Group Scribbles before, and the last one had never used Group Scribbles. This workshop was observed by two researchers taking notes (for observer triangulation), and the session was audio and video recorded. Additionally, teachers completed a survey regarding the workshop and the usefulness of the routines.

The teachers dedicated the first workshop hour to reflect on the design of activities using Group Scribbles and other technologies. We also intended to extract evidence about the design routines presented, to see whether they could enrich the teachers' designs. To do this, we asked teachers to design an activity that worked on a concrete educational content, from the point of view of two subjects: one established by us and another one left to their choice (e.g. for the educational content "Earth and the Sun", the teacher had to design an activity about this content through the subject of Spanish Language and another freely chosen subject). The activities were designed using pens, paper and sticky notes.

This kind of design task was very familiar for teachers, since it was related to the teachers' usual curricular contents: "I wonder if teachers will have understood what they are asked to do. ... As this first part evolves, I notice that the explanation was enough, since everybody does the task in a fast and centered way". As the external observers also point out in their notes, teachers were able to produce activity designs that were rather complex, despite the limited time allotted for the task: "Participants propose complex and elaborated designs, even if we thought that the time they had (20') would not be enough" (Observation notes. 25th June, 2010). Once these initial designs were finished, teachers shared them with the whole group.

After that, a number of paper cards were distributed, each one representing a design routine (see Section 4). The cards, as it can be seen in Fig. 6 (left), contained the name of the design routine, a brief explanation and two examples from activities where those routines had been applied. This way, after consulting the cards, teachers were asked to select one of the initial activity designs and to try and enrich it, using the provided design routines.

In Fig. 7, we can see an example of the "Elements of the Universe" initial design, selected by the teachers. In this initial design, after the "Brainstorming" phase, (phase 1 in the figure) the teacher opted for classifying the different elements of the universe, attending to the number of syllables (phase 2) and, finally, classifying the planets, putting them in alphabetical order (phase 3).

Next to the initial design in Fig. 7, we can observe how teachers enriched the initial design with some of the design routines presented. Thus, the teachers enriched the design using the routines "Search for information on the Internet" about the solar system (A in the figure) and "Where is on the image?" (B), so that students would have to write the names of the different elements that appeared in the image. The initial design was also enriched by means of a poll where students voted what to do next (C) and the introduction of other classification routines (D). Finally, the teachers added the "Summarize" design routine, in the form of a shared mural with all the concepts that had been worked on during the activity.

In the second hour of the workshop, teachers evaluated the usefulness of the enactment routines that had been identified (see Section 4). First, a warmup brainstorming took place, in which teachers had to write and share common problems that appeared frequently during their enactment of technology-enhanced learning activities. To do this, the aforementioned Group Scribbles application was used. After the brainstorming, the teachers were asked to simulate the enactment of the enriched design from the previous phase. The teacher who initially designed the activity had to play the role of the teacher, while the rest of the group had to play different roles of students, each with different characteristics (e.g. a student that copies the solutions from his partners, a student that has problems solving the task, a student who has problems in collaborating etc). From the external observers' point of view, probably the role-playing was the most enjoyable part of the session for the teachers "... they assumed their roles very well." (Observation notes. 25th June, 2010). After the simulation of the activity, cards representing the different enactment routines were handed to the teachers, with the aim of identifying whether they represented common, recurrent elements that appeared during their practice and, more specifically, during the activity simulation that had just taken place. As it can be seen in the right-hand side of Fig. 6, enactment routine cards showed the following elements: the name of the routine (in bold), a brief description (in italics), two routine usage examples and (in the top-right corner) the kind of task/phase in which the routines had normally appeared (explanation, support/task or evaluation).

In order to gather data about this workshop, the teachers were presented a survey with questions about how well the design and enactment routines mirrored their daily practices, and also about their perceived usefulness. The survey was answered in two phases: one in

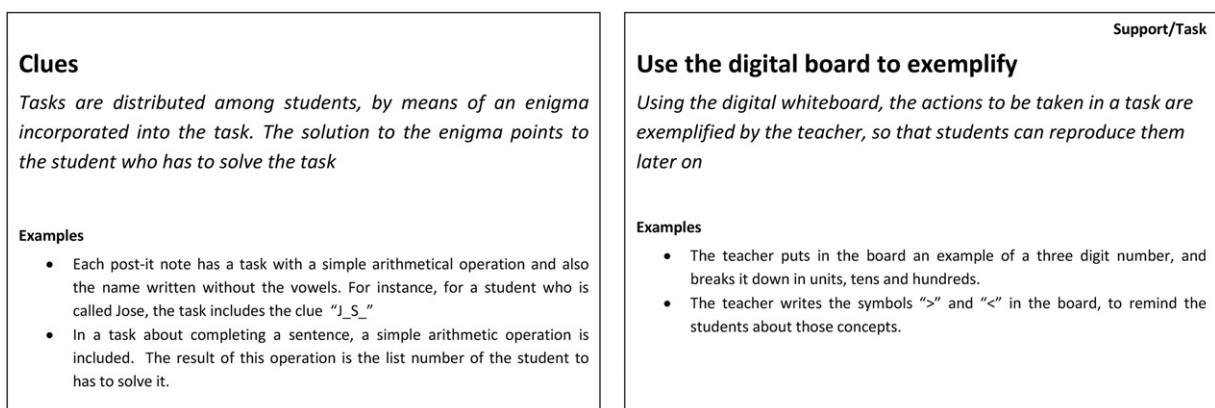


Fig. 6. Example cards of design (left) and enactment (right) routines.

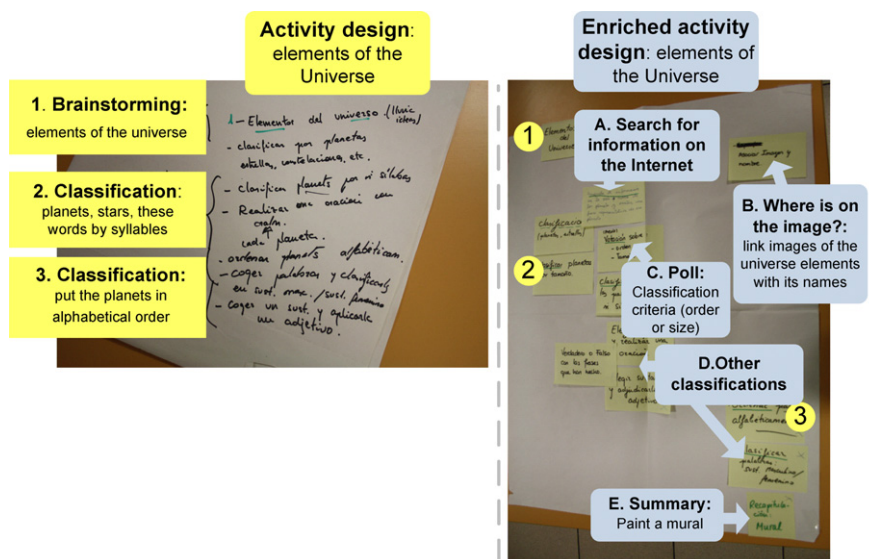


Fig. 7. Example of the initial activity design (left) and its enrichment with design routines (right).

the middle of the workshop, and another at the end of it. The workshop garnered very positive feedback from the teachers, of which fragments are presented below. Regarding the design routines, the teachers state that they have often used the identified routines, and one of them declares that she uses almost all of them. Moreover, the teachers stated that the use of the presented routines is not exclusive of activities with Group Scribbles, but rather of any kind of classroom activity. Examples can be seen in the following extracts from the survey:

To the question: *Have you ever used these design routines? Which ones?*

A: *Yes, almost all: brainstorming, classification, ordering, where is on the image? etc.*

C: *Yes, in fact, we used it daily without Group Scribbles.*

Teachers survey. 25th June, 2010

All teachers except one stated that design routines helped them in enriching the design of the activities. The remaining teacher had the opinion that the routines could also make the activity too complicated.

To the question: *Did the design routines help you in enriching the design? Why?*

A: *Yes, because it brings new ideas about how to work the same contents in different ways.*

C: *Yes, and to complicate it a bit.*

Teachers survey. 25th June, 2010

Regarding the enactment routines, teachers agreed that in the simulated activity that they enacted, many of the presented routines had appeared. Moreover, one teacher stated that it could be very interesting to review those routines before trying to use Group Scribbles. We can observe this in the following comments:

To the question: *Could any of the enactment routines be applied to the simulated activity?*

A: *Yes, both the explanation and evaluation routines. Although for most part they are used spontaneously.*

D: *Yes, I think that in the simulation, most of the enactment routines have appeared. Maybe it would be interesting to remind the usage of the tool before an activity with Group Scribbles.*

Teachers survey. 25th June, 2010

The teachers also agreed to the usefulness of enactment routines as a tool close to their daily practice. Additionally, the researchers' observation notes record the interest shown by one of the teachers, who expresses the usefulness of reviewing these routines before the enactment of ICT activities. This is shown in the following excerpts:

To the question: *Do you think these routines are useful for your practice?*

A: *I think that practice is a set of routines that each teacher applies to his daily practice. Thus, I think that the catalogue is useful.*

Teachers survey. 25th June, 2010

The session has ended at 12:10 a.m and "A" asked us if there is some place where routines were to be shared for the next academic year because, as the teacher said, "I think that for me it could be very useful to look up these routines and probably try to make different things with ICT in my classes".

Observation notes. 25th June, 2010

This workshop was an initial attempt to share design and enactment routines with the teachers, with the aim of gathering evidence about their potential usefulness in real educational contexts. As we can see, the feedback from teachers was very positive. This situation prompts us to continue working towards helping teachers to make their ICT practices more explicit, creating step by step a community of different practitioners that care about their practice in these TEL scenarios. We also need further efforts to identify and abstract from these routines, until they represent valuable responses to recurrent problems that teachers have to deal with in these scenarios.

6. Discussion

So far, we have seen how six months of fieldwork in an authentic primary school setting have brought us to the concept of design and enactment routines, as a way of structuring the orchestration of activities in the classroom. Also, we have seen how these routines can be represented graphically, and we have come to close the cycle by making those routines available to the teachers. Now, we will discuss some of the benefits of these findings both for teachers and for researchers, anchoring some of its aspects to relevant literature. We will also highlight some of the criticisms and limitations of the approach taken so far in this paper.

Regarding the advantages of this approach for practitioners, as it was mentioned in Section 2, this approach of looking for recurrent elements in a complex practice (in this case, teaching) and making them explicit as solutions to recurrent problems, is taken from the work about design patterns by Alexander et al. (1977). This kind of approach has proven very useful in helping non-expert practitioners to grasp complex practices in a variety of fields. Gamma et al. (1995) provides a clear example in the field of object-oriented software design, while Hernández-Leo et al. (2009) provides a closer example in the field of CSCL script design. Since currently the vast majority of teachers are not experts in the pedagogical application of ICT to education (as noted in Plan Avanza (2006) for the Spanish educational system), we believe that efforts towards making educational practices with ICT easier to grasp for non-expert teachers would represent a very worthy contribution.

The main advantages and usefulness of this approach are, for the most part, the same that can be encountered in design patterns literature for the usage of design patterns in other practices (Alexander et al., 1977; Gamma et al., 1995): this vocabulary of routines can serve as a tool for communication of experiences and best practices among practitioners and with researchers, and they can also serve as a tool for reflection and design for practitioners (by making practice, and the problems it aims to solve, explicit). Moreover, we believe that these routines could have an important role in making teaching practice with ICT more agile, by internalizing/automating certain aspects of the practice to which solutions already exist (thus avoiding “reinventing the wheel”). This would allow teachers to concentrate on other issues, such as the social and motivational aspects of the activity, which are much more dependent on context, and require high levels of attention and creativity from the teacher to be successfully solved.

Regarding the benefits for researchers and the graphical representations described in Section 4 provide a novel and powerful way to represent complex teaching practices such as the enactment of collaborative activities with multiple ICT tools. Our representations can be traced back to the work of Dillenbourg and others in the field of CSCL, where the task flow of a script of an activity is represented as jumping between different social levels (Dillenbourg & Hong, 2008). This kind of representation is also related to the task-swimlane form of representing learning designs (see Conole (2010) for an explanation and examples), but in this case enriched with a new set of elements, the enactment routines, which try to capture essential elements of teaching practice (i.e. how teachers do things) during the enactment. The representations depict the main elements of the definition of orchestration from Dillenbourg et al. (2009), with the sole exception of context. Since the analyzed activities all took place in the same context (a primary school classroom), this element was neglected in our analyses. However, if we are to take this approach to teaching practices that traverse contexts (e.g. blended learning activities), some way should be found to highlight the context where each part of the activity takes place.

However, the approach taken in this paper can be criticized from a number of standpoints. First of all, and given the means that have been chosen for the data gathering (mostly through qualitative studies in one concrete educational context), one may wonder to what extent the routines uncovered here are generalizable to other contexts. The answer to this is that on this first stage, the generalizability of the routines will be low. However, by iteratively refining the routines in additional contexts that are increasingly different from the original one, by consulting experts that know about many different settings (Meszaros & Doble, 1997, p. 529), and by progressively abstracting the routines (as done, e.g. in Winters and Mor (2009)), this generalizability can be increased.

Other dangers and tensions in this approach come from its relationship with the design patterns field of study, and some of its well-known issues. For example, the fact that the routines are derived from actual practice, makes routine-based practice less innovative. However, we can argue that by keeping the teacher on the safe side in some aspects of their practice (e.g. technology usage), we allow them to be more creative in other areas (e.g. the social/motivational ones). Another possible criticism is that it may make practice too rigid, if teaching is restricted to just using these routines. We currently conceive these routines, not as a complete catalogue of the possible actions for teachers, but rather as possibilities, which can be taken as-is, or combined in new forms, or that could serve as guides or inspiration for making their practice more creative. Finally, there is always the risk of “pattern-itis” (that is, to use as many patterns or routines as possible in over-complex designs, see Gamma, 2002). The answer to this is also simple: teachers should use these routines in good measure, since the quality of the learning experience does not correlate with the number of routines used in the enactment.

One last criticism will serve us to close this discussion and as a link to our future work: our set of routines, as they have been elicited so far, represents the practices of teachers with ICT in the observed classrooms. As such, we do not assert that these concrete routines, and the associated professional development initiatives described in Section 5, are applicable to all primary education classrooms. Also, we do not claim that the proposed set of routines are a complete solution, but rather that this sort of initiatives contribute to minimize current uncertainty in the effective use of ICT in current education. Indeed, the set of useful routines will be dependent on the socio cultural context of the school and classroom, and on the intent of each professional development initiative. Moreover, we cannot assert that all of these practices can be labeled as best practices. In fact, there is a heated debate in the area of pedagogy as to the existence of such thing as best practices. This way, design and enactment routines can be seen as good or bad depending on the objectives and values that teachers have in mind. Thus, the same activity design can be enacted by different teachers in totally different ways, according to their teaching styles. In this sense, the works of Mercer and Littleton (2007) and Vass and Littleton (2010), from a socio cultural perspective, have provided ample evidence that high levels of learning achievement do not depend solely on how teachers design and enact their activities. In those studies, classrooms differed in terms of their participation structures, and the quality of children's talk (e.g. whether pupils are taught how to talk productively or not, pupils' sense of agency on the process of learning, etc.) showed a strong impact on the quality of learning. Further efforts and initiatives on collaborative learning research, including work on collaborative dialogue in teacher thinking with technology (Wegerif, 2010), are needed. However, we provide initial evidence that the general idea of routines and its reflection back to teachers in professional development, has great potential as a way to help teachers in understanding and improving their practice, especially with ICT.

7. Conclusions

The increasing presence of ICT in all areas of our daily life highlights the need to provide students with learning experiences that reflect this change. However, we have come to believe that providing technological endowments to schools is not enough to enhance the learning of students. Nowadays, teachers are called to orchestrate ICT and non-ICT tools in a creative and effective way that leads to technology-enhanced learning. However, very little support is given with regard to *how* to do it. In this paper we have described one way for researchers to analyze everyday teacher practices in authentic settings, describing how teachers develop these complex activities through the use of routines.

The use of these routines as solutions to recurrent problems in teaching practice could prove useful not only to disentangle how teachers design their lessons, but also how those lessons are transformed into the actual classroom performance. Moreover, the preliminary evidences on the powerful mirroring aspect of the routines for teachers (i.e. they recognize themselves and their practice in those routines) points at its usage in professional development programs and other interventions aimed at influencing teacher practice, especially with non-ICT-expert teachers.

Our future work will be directed to ascertain which of the extracted routines are the most useful for teachers. Thus, most of our efforts should be put in trying to refine these routines so that they become useful and accepted solutions to recurrent problems, that are easier to identify by teachers. In order to achieve this, processes similar to the one described in this paper can be put in practice in other educative contexts, to gather evidence about the generalizability and scalability of this approach.

In a parallel effort towards eliciting more of these routines, as well as to further our goal of fostering CSCL practices in the mentioned primary school, we are currently promoting a simple technological platform for sharing and reusing activity designs with ICT and narrative experiences about the enactments of those designs. This platform, called CREa-TIC³ intends to support a community of practice (Wenger, 1999) that uses these routines as a mediating tool. CREa-TIC also can be used to help us develop this catalogue of recurrent elements of teaching practice.

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³ Available online at <http://gsic.uva.es/CREa-TIC/> (in Spanish; Last visit: 12 Nov 2010).

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