TELMA case study on cross experimentation

"Extensive exchange between scientists, practitioners and politicians are essential if we want to increase science-based teaching and educational decision-making". Carmen Zahn Kaleidoscope Member

1. Contextual information on your research activity

- Stage of your research -beginning, middle, end- (*conceptual design, test bed and evaluation)*

- Explain the ***objectives*** of your research

This contribution deals with the work of the European Research Team TELMA (Technology Enhanced Learning in Mathematics) of the Kaleidoscope network towards understanding the role played by theoretical frames in design and research in that area, and building tools to improve communication between researchers from different cultures. We present two facets of TELMA work: a 'cross-experimentation' project in which each TELMA team experimented with an Interactive Learning Environment (ILE) for mathematics designed by another team; and the design of a methodological tool for systematic exploration of the role played by theoretical frames in the design and analysis of uses of ILEs. On the one hand, the cross-experimentation aimed to explore the didactical functionalities the different teams involved would associate with ILEs they had not designed, and how their particular educational contexts and the theoretical frames they used would influence their constructions. On the other hand, this notion was also used to structure the methodological tool for exploration of the role played by theoretical frames.

- Explain the present and expected ***results***

This work tries to overcome the difficulties generated by the existing diversity of theoretical frames and the lack of communication between these, through a better understanding of the role played by theories, the development of methodological tools and cross-experiments. This is on-going work and all the analysis being completed, we hope to be able to offer a sound contribution on these difficult but crucial issues.

2. Case study analysis

2.1. SYNTHESIS INFORMATION

name of the case study	Cross experimentation
Short description (maximum 10 lines)	This contribution deals with the work of the European Research Team TELMA (Technology Enhanced Learning in Mathematics) of the Kaleidoscope network towards understanding the role played by theoretical frames in design and research in that area, and building tools to improve communication between researchers from different cultures. We present two facets of TELMA work: a 'cross-experimentation' project in which each TELMA team experimented with an Interactive Learning Environment (ILE) for mathematics designed by another team; and the design of a methodological tool for systematic exploration of the role played by theoretical frames in the design and analysis of uses of ILEs. We focus on the methodological dimension of this work, showing how we employ the construct of *didactical functionalities* as a means of comparing and integrating the research conducted by the teams. We provide some preliminary results of the joint experiment and use of the methodological tool.
territorial level	❑ international ❑ national ❑ regional ❑ local
nature of the case selected (policy, initiative, action…)	Field research

2.2 DESCRIPTION

- What were the key reasons this initiative originated?

This contribution originates from TELMA, a European Research Team (ERT) established as one of the activities of Kaleidoscope, a Network of Excellence (IST–507838) supported by the European Community (www.noe-kaleidoscope.org).
Kaleidoscope's central aim is to address the lack of harmonised research in the field of Technology Enhanced Learning (TEL) in Europe by integrating various existing initiatives and research groups. The aim is to develop, on the one hand, a rich and coherent theoretical and practical research foundation, and, on the other hand, new tools and methodologies for an interdisciplinary approach to research on learning with digital technologies at a European level. The

network is doing this by supporting a range of integrating actions, including *European Research Teams* (ERT) such as TELMA. ERT are integrating activities, which aim to network European excellence through specific research challenges. The key idea of creating an ERT is to stimulate the mutualisation of knowledge and know-how of a number of recognized research teams on the identified issues, and to favour the construction of shared scientific policy, building complementarities and common priorities.
More is available at the TELMA web site (www.itd.cnr.it/telma).

- What are/were the main objectives?

On the one hand, the cross-experimentation aimed to explore the didactical functionalities the different teams involved would associate with ILEs they had not designed, and how their particular educational contexts and the theoretical frames they used would influence their constructions. On the other hand, this notion was also used to structure the methodological tool for exploration of the role played by theoretical frames.

- Who are the target users involved in this case study (profile, socio-cultural features)?

The main users of the cross experimentation are researchers.
In fact the cross experimentation involves six European teams of researchers in the field of technology enhanced learning. Each team has brought with it particular focuses and theoretical frameworks, adopted and developed over a period of time. Most of the teams have also contributed learning environments integrating digital technologies for use in mathematics learning, designed, developed and tested in accordance with their own theoretical perspectives[1]. We will refer to these as Interactive Learning Environments (ILEs).

- How are/were they involved?

The starting phase was very challenging, requiring six teams with different backgrounds, work methodologies, and ILEs, to begin to share knowledge, developing a common language and common topics of interest. This demanding task was addressed by working on a number of topics considered important for mutual knowledge and comparison (including research areas and goals, theoretical frames, ILEs implemented or used, contexts, work methodologies). Each team had responsibility for one topic and, on the basis of materials sent by the other teams, produced a report analysing the different contributions and developing them into an integrated presentation (the result is available the TELMA web site (www.itd.cnr.it/telma).
This first effort, based on the descriptions provided by the teams and analysis of papers they had published, helped to identify some common sensitivities to,

[1] For instance Ari-Lab2 (CNR-ITD), Pepite and Casyopée (DIDIREM), Aplusix (MeTAH), E-slate (ETL), L'Algebrista (CNR-ITD and UNISI).

for example: the contextual, social and cultural dimensions of learning processes; the role played by semiotic mediation; instrumental issues. It also made it evident that the diversity of the theoretical frames we employed[2] affected the ways we dealt with these common sensitivities in the design or use of ILEs. But reading and exchanging descriptions and research papers left researchers unsatisfied as they felt that their understanding of the underlying processes and their possible effects on practice remained too superficial. For that reason, they decided to develop a strategy allowing them to gain more intimate insight into their respective research and design practices. This strategy consisted of a 'cross-experimentation' project and simultaneous development of a methodological tool for systematic exploration of the role played by theoretical frames in teaching and learning in mathematics using digital technologies.

- What are/were the end users' expectations and concerns in relation to the case study?
    - concerns regarding tool ergonomy
    - concerns regarding the characteristics of the implementation of mathematical objects and of the relationships between these objects
    - concerns regarding the possible actions on these objects
    - concerns regarding semiotic representations
    - concerns regarding the characteristics of the possible interaction between student and mathematical knowledge
    - concerns regarding the characteristics of the possible interaction with other agents
    - concerns regarding the support provided for the professional work of the teacher
    - concerns regarding institutional and/or cultural distances

- Could you please describe the organisational features of the case study (e.g. management, funding, structure of the initiative, lifecycle positioning)?

The idea of cross-experimentation is a new approach to collaboration, seeking to facilitate common understanding across teams with diverse practices and cultures and to progress towards integrated views.
There are three principal characteristics of this cross-experimentation:

- the design and implementation by each research team of a teaching experiment making use of an ILE developed by another team;
- the joint construction of a common set of guidelines expressing questions to be answered by each designing and experimenting team in order to frame

[2] These were mainly: activity theory, socio constructivism, Vygotskian theories of semiotic mediation, social semiotics, theory of didactic situations (TDS), anthropological theory, Rabardel's theory of instrumentation, situated abstraction, AI theories.

the process of cross-team communication;

- the specific role given to PhD students and young researchers.

Each team was asked to select an ILE among those developed by the other teams. This decision was expected to induce deeper exchanges between the teams, and to make more visible the influence of theoretical frames through comparison of the vision of didactical functionalities developed by the designers of the ILEs and by the teams using these in the cross-experimentation.

The cross-experimentation involved a rich diversity of ILEs, educational contexts and theoretical frames, but important attention was paid to the control and productive exploitation of this diversity, especially through the joint construction of guidelines, developed through an on-line collaborative activity. On-line collaboration allowed the teams to communicate the results of their within-team discussions and resulted in an agreed joint set of guidelines (http://www.itd.cnr.it/telma/documents.php), negotiated between the teams to be as relevant as possible to their interests and theoretical frameworks, while remaining feasible in light of the constraints of time and empirical settings. These guidelines structure and support a priori and a posteriori reflective analysis of the cross-experimentation.

In order to allow as much comparability as possible between the research settings, it was also agreed to address common mathematical knowledge domains (fractions and algebra), with students between years 7 and 11 of schooling in experiments lasting approximately one month. Table 1 summarises the ILEs chosen, the teams who developed the ILEs and the teams conducting the experimentation.

An important role has been given to young researchers and PhD students. Starting from three draft sets of questions addressing the issues of contexts, representations and theoretical frames, they developed the guidelines through the Kaleidoscope Virtual Doctoral School platform, and have taken charge of the experimentation. This role is coherent with the general philosophy of TELMA and Kaleidoscope. It also has the benefit of allowing “fresh” eyes to look at the teams’ approaches, theoretical frameworks, and consolidated practice in order to make explicit those factors that often remain implicit in the choices made by more experienced researchers.

ILE	Developer’s team	Experimenting team(s)
Aplusix	MeTAH-Grenoble	CNR-ITD, UNISI
E-Slate	ETL-NKUA	UNILON
ARI-LAB 2	CNR-ITD	MeTAH, DIDIREM, ETL-NKUA

Table 1: The tools employed by TELMA teams in the cross experiment

The selection of research questions, experimental settings and modes of use of the ILE, methods of data collection and analysis were all determined by each experimenting team after a period of familiarisation with the ILE itself, following the common guidelines developed through the on-line activity. Each team thus conducted an independent study of the use of an ILE. At the same time, however, the framework of common questions provided a methodological tool for comparing the theoretical basis of the individual studies, their methodologies and outcomes.

2.3 ANALYSIS

- How are you collecting user's input and/or feedback? *(please choose if used)*

  ☐ Specific meetings at the beginning and during the project.
  ☐ We invite them to project meetings.
  ☐ We take advantage of events or meetings organized by others to interview users, present results, test results, etc.
  ☐ We do face-to-face interviews.
  ☐ We do telephone interviews.
  ☐ We do online surveys.
  ☐ We discuss exploitation of our results with users.
  ☐ We ask users to test the usability and usefulness of the tools developed.
  ☐ Others:____

- What is /has been the **impact** of the case study on the **target users**? Have their expectations been met?

In order to point out and compare the preliminary results of the cross experiments a meeting was held. Each team reported on its own experiment focusing on the defined/employed didactical functionalities of the ILE used, trying to make explicit the relationship between such didactical functionalities and the team's theoretical assumptions. In order to structure this preliminary analysis each team was asked to complete a form before the meeting, focusing on the three dimensions of didactical functionalities. The form followed the principle of "necessary conditions" in the sense that not all the details of the experiments needed to be given, but only those that the team believed to be necessary conditions for the experiment to be successful according to the team's theoretical assumptions (http://www.itd.cnr.it/telma/documents.php).
Comparison of the forms completed by each team, and of the oral reports of the experiments, highlighted the need to Adapt the way in which an ILE is used to a changed context. The impact on target users has increased as long as specific theoretical frameworks and cultural and/or institutional constrains have been taken into consideration and adequately dealt with.

- What is the **broader impact** at macro level?

- Are there **unexpected** side effects?

During the cross experiment some difficulties arose when teams attempted to use a given ILE in a context (both in the sense of school and of research context) different from that in which it had been developed. For example, the software Aplusix has been designed (by the French team MeTAH) to facilitate the teacher's work, and to offer him/her a good level of autonomy with respect to standard algebra curricular activities. The software allows students to build and transform algebraic expressions freely and to solve algebra exercises by producing their own steps as on paper; for each step the system gives an indication of correctness as feedback. Aplusix was designed to support the standard activity of algebraic manipulation, based on the solution of calculation tasks like *expand*, *factorize*, *solve the equation*, etc. However, the CNR-ITD team, adopting a socio-constructivist approach, faced the problem of planning open-ended tasks. According to this theoretical framework, open-ended tasks favour pupils' construction of meanings through exploratory activities. This was achieved by interpreting the feedback concerning the correctness of steps as feedback concerning the equivalence of expressions and/or statements. This change of perspective implied also that Aplusix was no longer used autonomously by students, but required the teacher to orchestrate the activity by asking the students to make their strategies explicit, to justify them and to discuss them with their classmates.

Adapting the way in which an ILE is used to a changed context, even if possible, may also be complicated by the role played by different curricular constraints and school praxis. As an example, we consider ARI-LAB2 (developed in Italy by the ITD team). ARI-LAB2 is composed of several microworlds designed to support activities in arithmetic problem solving and in the introduction to algebra. One of these is the "fraction" microworld, which provides a graphical representation of fractions on the real line, allowing the user to build fractions by means of commands based on Thales theorem. Some teams encountered difficulties using this microworld in their school context due to the fact that Thales theorem is usually introduced in the curriculum later than fractions. The MeTAH team tried to use it as a "black box" but found this caused problems when pupils needed to make sense of feedback. Similarly, the DIDIREM team decided to switch to other microworlds of ARI-LAB2 because they judged it was not realistic to ask a teacher to change the mathematics organisation of the school year.

During the cross-experimentations another aspect has been highlighted related to the influence of theoretical frameworks on the use of ILEs. This is related to the role assigned to feedback by different teams. For example, the DIDIREM team, drawing on the theory of Didactic Situations, found the feedback provided by ARI-LAB2 too limited with respect to what is generally expected from a "milieu" offering an a-didactic potential for learning. On the contrary the ITD team, who had developed the ILE, drawing on a more general constructivist framework, considers the feedback sufficient because the teacher's role and feedback are considered as fundamental as those of the ILE.

- What are the elements of **innovation** (in terms of methodology and processes, in organisational terms, in relation to the pedagogical, economic, technological, socio/cultural dimension)?

See below

- What are the good practice elements (with specific reference to transferability, coherence, efficiency, and sustainability of the case study)?

The main elements of innovation and good practice of the cross experimentation can be summarised as follows:

<u>Making the implicit explicit</u>

Nowadays most of the approaches to technology enhanced learning in mathematics acknowledge the necessity of focusing not only on the specific characteristics of the technology employed but of adopting a more integrated perspective where importance is assigned to aspects such as, for example, theoretical and epistemological choices, contexts of use, social interactions, educational strategies, role assigned to the teachers (Bottino, 2004). This is true also for the approaches adopted by TELMA research teams. Nevertheless, the teams do not address the above-mentioned aspects in the same way, and the cross-experiment revealed differences in goals and focuses of attention. The observed differences depend on cultural backgrounds, on the adopted theoretical frameworks, and on different ways of approaching and conceiving research in maths education. In other words, there is a set of assumptions which often remain hidden, and which are made explicit only at a reflective theoretical level. The TELMA cross-experimentation approach required researchers to put in practice their views, but also to compare their own approach with that of the other teams. In this way, differences among the teams could be made explicit, increasing teams' awareness of their priorities and assumptions. For instance, in the experiment carried out by the DIDIREM team (France), main reference was made to the Theory of Didactic Situations (Brousseau, 1997) and to the anthropological approach (Chevallard 1992). As a result, in the pedagogical design of the experiment, priority was given on the one hand, to the characteristics of the 'a-didactic milieu'3 and, on the other hand, to institutional values and constraints. The pedagogical design was asked to maximize the cognitive potential offered by the milieu, seen as an antagonist system with respect to the student. This made the researchers especially sensitive to the feedback offered by the ILE used. The design was also asked to be manageable in an ordinary classroom. This made the researchers especially sensitive to the distance with the usual institutional context, and to the necessity to keep this distance manageable by the teacher. Other aspects, even if considered interesting, were less emphasized (e.g., collaborative work among students, teacher's role). On the contrary, the CNR-ITD team (Italy), mainly

[3] In the Theory of Didactics Situations, a situation is modeled as a game and the "milieu" was initially defined as the system opposing the student in this game.

referring to socio-constructivism and Activity Theory (Cole & Engestrom, 1991; Engestrom, 1991; Vygotsky, 1978) assigned a priority to social construction of knowledge and to the role of the teacher. Therefore, the experiment carried out by this team was mainly focused at investigating these issues while less attention was paid to other aspects (e.g. the detailed organization of the milieu within which learning is expected). Many choices (e.g. tasks to be faced during the classroom activities and explicit orchestration of the work) were not detailed by the experimenting team, as done by the French ones, but left to the teachers while carrying out the classroom activities.

<u>Clarifying the relationship between theoretical assumptions and experimental choices</u>

In the above-mentioned example, the CNR-ITD team set up its classroom experiment giving priority to the role of the teacher in the social construction of knowledge (consistently with the socio-constructivist approach and Vygotskyan theories).

Setting up the actual classroom experiment, the ITD researchers faced the necessity of finding a way to precise, in practice, the role that the teacher had to assume, since the theoretical frameworks of reference gave only some general indications but did not provide a method to define it. In general, a theoretical framework can influence an experiment at a global level, but when going into details, there are issues that need to be directly addressed by the researchers. In other words, there is a sort of gap between what it is offered by a theoretical framework, and what it is needed by the researchers when planning a classroom experiment. Such gap is determined by the steps (often implicit) that a research team has to undertake to move from theoretical reflections to experimental practice. The cross-experimentation helped TELMA teams to articulate some of these implicit steps by means of a comparison among the different experiments. A team referring to a given framework may view the work of another team under a different perspective, helping the individuation of gaps between a theoretical position and the experimental practice. In this sense, we report the case of the DIDIREM team which is particularly familiar with addressing the roles played in learning processes by “ruptures” and “obstacles”, as they are key elements of the theory of didactic situation which this team refers to. During the cross experimentation, the DIDIREM team observed how the Siena team assumed Vygotsky’s framework (Vygotsky, 1978) which describes the importance of “ruptures” and “obstacles” but which does not provide explicit methodological tools for putting these ideas in practice; nevertheless, as observed by the DIDIREM team, the Siena team successfully set up an experiment where “ruptures” and “obstacles” were exploited as means for achieving a specific educational goal. The DIDIREM team expressed the will to understand how the Siena team put in practice such a principle, which started a discussion to clarify (at least partially) the gap between the Siena team’s theoretical assumptions and how they put them into practice (which is certainly an original part of the team’s work).

<u>Adapting tools to new cultural and institutional contexts</u>

One of the issue addressed by the TELMA cross experimentation, is the way in which the teams addressed the task of adapting an ILE to a context different from that for which such tool was designed. With this respect let us cite the two French experiments involving the use of ARI-LAB2 an ILE for arithmetic problem solving and for introducing algebra (Bottino & Chiappini, 2002) developed by the CNR-ITD4. One of the microworlds which ARI-LAB2 is composed of is the “Fraction” microworld. Such microworld provides a graphical representation of fractions on a line: representations of constructions of (and operation between) fractions are based on Thales theorem. Because Thales theorem is usually introduced in the French curriculum later than fractions, French teams met difficulties in using this microworld in their school context. In fact, on the one hand the MeTAH team tried to use it as a “black box” but found this caused problems when pupils needed to make sense of feedback. On the other hand, foreseeing this difficulties the DIDIREM team decided not to use that microworld at all. On the contrary from ITD perspective this curricular issue was in a sense a minor concern: the teacher was assumed to be able (and in charge) to manage also situations where not everything is explicitly explained, freely exploiting pupils’ relationship with the ILEs and their feedbacks.
These different theoretical positions, supporting the design of the tool and of the experiment, were made explicit during the TELMA cross experiment, by means of comparisons of teams’ experiments and answers to the guidelines questions. As a consequence, after the first analysis and comparison of classroom experiments, the DIDIREM team hypothesised more clearly that even within their scholastic context it could be possible to experiment ARI-LAB2, but under certain conditions, such as switching to long term experiments instead of short term ones.
In conclusion, the cross experimentation, centred on the comparison between developing and experimenting teams helped making explicit each team’s assumptions and led to two main results. On the one hand, the assumptions lying behind the design of the tool were made clearer, and, on the other hand, the developers were provided with new ways of employing their tool.

- What are the key reasons of success/failure in users’ involvement and the lessons learnt?

The cross experimentation experience show how, in order to employ an ILE in a context different from that taken as reference by its designers, one has to face a set of problematic issues. To sum up, the highlighted issues include:

- educational goals
- typologies of tasks proposed to the students
- computer’s feedback and autonomy of the ICT tool and/or of the pupils
- settings and role of teachers

These issues point to significant investigative directions to be addressed in the next year of the work of TELMA. In fact, in order to refine the comparison

[4] There are many cultural and institutional differences between Italian and French School (e.g. different curricular constraints and school praxis) and research approaches

between the experiments, our preliminary analysis raises the need to refine the lenses through which the experiments are analysed and compared. Starting from the idea of didactical functionality, we need to address its three dimensions in more detail, and in order to do so, a first methodological tool has been developed in parallel with the preliminary analysis and will be refined and employed in the next year.

Annex I . Communication with other researchers

How to communicate with other researchers?

Examples:

☐ We communicate our progress to other universities/organizations every quarter
☐ We inform them about expectations collected from users
☐ We communicate through informal meetings
Others:____

- What ***technologies/results*** do you need to perform correctly your research?

Interactive Learning Environments (ILEs) (see above for more explanations)

- Describe the ***relevant documentation*** you wrote about your project *(public and private)* and where it has been published.

Artigue M. (ed.) (2005). Towards a methodological tool for comparing the use of learning theories in technology enhanced learning in mathematics. http://www.itd.cnr.it/telma

Cerulli M., Pedemonte B., Robotti E. (2005): An integrated perspective to approach technology in mathematics education. Proceedings of CERME 4, Fourth Congress of the European Society for Research in Mathematics Education 17 - 21 February 2005 in Sant Feliu de Guíxols, Spain.

Developing a joint methodology for comparing the influence of different theoretical frameworks in technology enhanced learning in mathematics: the TELMA approach, TELMA (KALEIDOSCOPE) European Research Team1: < Artigue M., Bottino R., Cerulli M., Mariotti M., Morgan C.> & <Alexopolou E., Cazes C., Chaachoua H., Georget J.P., Haspekian M., Kynigos C., Lagrange J.B., Latsi M., Maffei L., Maracci M., Papadopulou A., Pedemonte B., Psycharis G., Robotti E., Souchard L., Trgalova J., Vandebrouk F.>
Kaleidoscope TELEARN open archive initiative

Annex II. Exploitation of results

In your opinion, the ways to get good exploitation of results are:

☐ Exploitation should be discussed earlier in the project
☐ We should keep a long-term relation with industry
☐ We should try to contact the industry for advertising/sponsorship issues
☐ Ask industry for regular feedback (as they have cyclic business pressures).
☐ Try to build up a long term relationship with industry

☐ Others:______________________

- Explain the ***market research*** done recently.

Not applicable

- Are you updating information of your ***competition*** before, during and after the project? Please explain the information you have.

Not applicable

- What about ***prices***? Do you know how much do you want to sell it for? Are you aware of how much the customer wants to pay for it?

Not relevant (see below)

- Explain discussions with users about ***exploitation issues*** (industry, policy makers or end users).

More than market exploitation, use for educational purpose is foreseen. The cross experimentation is expected to be useful in educational environments