OPPORTUNITIES FOR LEARNING WITH DIGITAL TECHNOLOGIES: A QUESTION OF RECONTEXTUALISATION

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Many visions of opportunities for learning provided by digital technologies have been advocated by researchers, using a large diversity of frameworks. Here I consider only a small set of these:

Theory of Didactical Situations (TSD): learning occurs via the interaction with an antagonist milieu, and the institutionalisation of knowing into official knowledge. Technology can be constituent of a suitable milieu (Laborde & Caponni 1994).

Anthropological Theory of Didactics (ATD): learning is developing an adequate relationship to "objects of knowledge" within an institution (Chevallard 1992).

Constructionism: learning is abstracting in situation and constructing a web of meanings. Digital technologies help to provide rich environments where abstracting and webbing meanings are possible (Harel Papert 1991).

Instrumental approach (IA): Learning mathematics with a digital media is through a process of instrumental genesis involving both knowledge of the tool and of mathematics (Verillon et Rabardel, 1995).

The contrast between these visions and the limited impact they have on school practises, as well as the fragmented multiplicity of frameworks in which they are expressed, suggest that visions are tied not simply to the frameworks that researchers privilege but rather to a whole context in which their activity takes place. My assumption is subsequently that opportunities for learning have to be thought of as strongly depending on context especially when using technology. The question is then how to recontextualize opportunities for learning from one context to another.

1. Context and digital media for learning mathematics

Research in the uses of digital media is generally characterized by interventionist agendas and design research methods: conception of innovative educational environments based on particular use of digital technologies, study of what happens as they intervene in school settings. Designers of digital technologies shape their tools from their perceptions of learning mathematics and their epistemologies of mathematics and mathematical activity as well as on the rules and constraints of software production and dissemination, while users shape their conceptualizations of the nature of these media in a process of instrumental genesis also influenced by perceptions and epistemology together with rules and constraints of schools and classrooms. From this relationship of research on the use of digital media to context, particular objects emerge to analyse opportunities for learning. (1) *Participants' behavior* in empirical research is most often a basis for proof of enhanced learning. (2) *Tools and scenarios* are offered by research especially in technology to support evidence of opportunities for learning. Created in a given context, the use of these

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resources can be problematic in other contexts. (3) *Theoretical frameworks* are finally necessary to communicate about opportunities for learning. Recently in the stream of research about frameworks in math education, interest grew upon the role of communities and cultures which are aspects of the context.

Contextual characteristics also emerge to describe how research activity affects the above objects. Characteristics of *empirical settings* are teachers, students and other actors taking part in the empirical research, their relationship with the artifact(s), and between them, as well as policies and pedagogic norms at several levels from school, to curriculum and assessment regimes, and to national education systems and, etc. Characteristics in *academic settings* include the institutional and cultural environment within which researchers work, particularly the relationships to and expectations of funding agencies, their positioning in relation to colleagues locally, nationally and internationally as well as their relationships with teachers and school for empirical research. In order to give an evidence of the entangled web of relationship between visions of opportunities for learning and contextual characteristics, and to initiate a reflection on recontextualisation, I take the work of the research teams from across Europe brought together through the ReMath project.

2. ReMath: Tools to address the issue of context

The ReMath project carried out 'cross-experimentation', i.e. design and analyses of uses of a series of 'Didactic Digital Artefacts' (DDA) by different teams in different contexts (Lagrange et al 2010). The project went further to engage in developing cross-case analyses i.e. a unified associative/comparative account of two studies of the same DDA. Below I develop what can be learnt about contextual issues from one cross-case study involving the DDA Cruislet, carried out by a Greek team in charge of the design of this DDA, and Didirem, a French team developing another DDA, Casyopée. Cruislet is a navigation microworld in which a user flights aeroplanes across the Greek geography by issuing navigation instructions in either graphical/Cartesian or spherical/polar coordinate systems, in direct stepwise mode or by way of LOGO programming. Aeroplanes' movements are defined as vectors, and must take into account not only location, but also the elevation of the landscape they are navigating. Among the six ReMath DDAs, Cruislet is extreme in terms of distance of the tool from usual curriculum. The knowledge at stake with this DDA is at the interface between geography, mathematics and programming. In Greece, a rather long experimentation was organized in grade 10 classes (20 hours) without apparent difficulty while in France, making the use of Cruislet compatible with institutional constraints, resulted in a shorter experiment (6 hours) in the specific settings of project sessions. Moreover in France the negotiation of the scenario with the teachers in charge of the experimentation was a rather difficult process. The influence of the *empirical settings* is then immediately visible in the two scenarios.

With regard to *academic settings*, references to constructionism led the Greek team to consider this experimentation as the study of students' gradual mathematizations in an

environment where constructions are journeys using the varied systems of reference and the varied mode of operating. This led the Greek team to especially build on the potential offered by the complex linkage of representations offered by Cruislet for investigating the mathematical meanings that students construct regarding the notion of function as co-variation while navigating in 3D large scale space. The situation is radically different for the French team whose global references are IA, ATD and TDS (above). IA led to pay particular attention to the instrumentalization needs of such a DDA, so complex and so far from algebraic tools or dynamic geometry environments, and to try to find ways of limiting these needs. ATD made French team especially sensitive to the distance with the French curriculum and the attention to be paid to the possible ecology of Cruislet in the French educational system. For French researchers, epistemology is a top concern but they could not rely for supporting their scenario on a stabilized didactic knowledge because the literature regarding the objects implemented in Cruislet is not enough developed. In such conditions, controlled design consistent with TSD became impossible.

3. Cross-analysing a Cruislet experiment

In the cross-analysis the French team did a close study of the Greek experiment and the Greek team provided more data about the epistemological bases of the scenario and a precise account of students' behaviour. For instance, the Greek team reported on a situation based upon the use by students of a procedure that made one aeroplane perform a flight to an arbitrary position while another reached a dependent position, each of its coordinate being a linear function of the coordinates of the first one. Using this procedure first as a black box and then decoding the procedure, students could make sense of the situation by investigating the co-variation of the planes and conceiving the first plane's position as an independent variable and the second plane's position as a dependent variable. The cross-analysis made clear that Cruislet could provide opportunities for constructing the notion of function as co-variation while navigating in a realistic 3D large scale space. Functions as model of co-variation was also a domain of interest for the French team especially for the design of its own DDA, Casyopée. However, the domain of co-variation at stake in Casyopée is 2D geometry and the functions are one variable real functions. In addition, Casyopée is designed to provide opportunities for learning about polynomial, rational or transcendental functions rather than linear functions. Thus, when designing the scenario, French researchers, although informed by the Greek team of the tasks prepared by this latter team, saw these tasks as very far from what they used to propose to the students. It is worth to note that, in the constructivist tradition, no a priori analysis of students' behaviour was made by the Greek team for the cross-experiment, which did not help the French team to recognize the potential of these tasks for their scenarios. On the contrary, the cross-analysis of the Greek Cruislet cross-experiment, focused on the students' behaviour and a better appreciation of constructionism, pointed out an approach to functions that could be very complementary to the approach with Casyopée.

In the cross-experiment, the French team was attracted by features of Cruislet offering opportunities to link mathematics and geography in a multidisciplinary approach also favoured by the realistic context of Greece, and to introduce students to programming. To take advantage of these features, the French team conceived objectives for the teaching experiment far from the curriculum and this is the reason why the experiment was short and in the frame of a special project. In the a posteriori analysis of the first experiment, it appeared that the scenario had a certain potential to promote new teaching/learning situations but also that students' poor instrumental genesis of Cruislet limited opportunities for learning. This misappreciation by the French team can be put into relation with several contextual characteristics.

Contextual characteristics in the empirical settings : Experimenting Cruislet, the French team did not consider the qualitative approach of functional dependencies proposed by the Greek team because of the distance from the curriculum and usual practices and because of the constructionist framework in they were formulated. They rather imagined other opportunities for implementing Cruislet consistent with new trends of the curriculum towards seeing mathematics in coordination with other disciplines and towards the development of an algorithmic approach. The French team identified these trends as an opportunity to implement an experiment with Cruislet, breaking with current practices, but nevertheless providing a response to specific institutional demands.

Contextual characteristics in the academic settings : Casyopée was conceived in close relationship with a group of teachers that were chosen not because they were specially "innovation oriented", but rather because of their ability to create, experiment and disseminate situations that could be acceptable for other teachers. The accompanying epistemology of functions was developed with the idea of real functions of one variable in mind, which seemed to be the easiest notion to implement in the "ecology" of French upper secondary classes. Researchers had some notion of constructionism, but did not consider sharing this with teachers. The epistemology of functions was questioned when researchers and teachers had to look closely at the Greek experiment in the cross-analysis. They recognized that the tasks designed and implemented by the Greek team in a different ecology had the potential to introduce students to a wider understanding of functions that could be useful to consider before or in parallel with the development of competencies in the domain of real functions of one variable favoured by Casyopée use. Looking closely at constructionism in the cross-analysis of the Greek team experiment was also an opportunity to reconsider this approach, and to discuss with the teachers, in the light of a similar field experiment.

4. Contextual characteristics and visions

The context of a team working in the field of mathematics education and technology like the French team can be described as an entanglement of contextual characteristics both in the empirical and academic settings. Cross-analyses like the Cruislet case pointed out how this context was supportive for the team's research activity, but also

oriented its vision of technology and learning. They also brought support for opening the view: the team could enlarge its epistemological view of the notion of function, and of approaches to this notion using technology and consider the value of a framework like constructionism. This work carried out in common by researchers and teachers was the basis of a publication accessible to French teachers (Lagrange, Le Feuvre, Meyrier 2010) that proposed uses of Cruislet inspired by the cross-experimentation and adapted to the French context, as well as of a reorientation of the Casyopée project towards clarifying its potentialities. This highlights the need to go beyond broad decontextualized visions, to identify contextual characteristics and their influence, and also to use special methods for recontextualizing, as means to respect and encourage diversity in classroom use of technology.

5. References

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