Chapter 7
Digital Technology and Mathematics Education: The Teacher Perspective in Mathematics Education Research—A Long and Slow Journey Still Unfinished

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7.1 Introduction

Roughly two decades have passed since a UNESCO report (1992) gave an overview of the impact of computers and calculators on mathematics education at the end of the eighties and in the early nineties. Following the first ICMI Study on technology (1985), the editors wished to update some outcomes of this study and to republish some others in order to make them available to mathematics educators throughout the world. In the chapter entitled "Teacher education and training", Bernard Cornu declares:

> However, computers are now very common in society; they are used in many domains of daily life. In many countries national plans for computer equipment in schools have been achieved, and so a lot of computers are available in schools. Much educational software has been produced, and it is often of high quality. The use of computers does indeed become easier. […] Current and future teachers must be prepared for this evolution. It is not enough to master the knowledge and some pedagogical strategies and tools. Teachers must be able to deal with all the evolution which will happen, and to adapt to different kinds of pupils (pp. 87–88).

Despite significant advances in technological tools and environments for mathematics teaching, and in educational research related to this field, it is hard to claim nowadays that encouraging teachers to integrate technology into their practices is no longer necessary or a priority among institutional policymakers. In a recent UNESCO report (Artigue 2011), Michèle Artigue, referring to the 17th ICMI study (Hoyles and Lagrange 2010), states:

> Technologies have undeniably enriched the possibilities of experimentation, visualisation and simulation; they changed the relation to calculation, the relation to geometric figures. […] However, in spite of their undeniable potential for enhancing the teaching and learning

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> of mathematics and their many positive achievements, they have to date had little effect even in education systems that strongly encourage their use. Recent work on teachers' practices in computer environments is beginning to give insights into this situation, and forms of training properly adapted to teachers' needs are being considered. Nevertheless, the issue of widespread effective use of these technologies in basic mathematics education remains for the moment unresolved. (p. 35)

Indeed, research focusing on teachers' practices in mathematics classes is a relatively recent phenomenon within the history (even though short) of mathematics education and technology. During the first decade of use of technology the role of teacher and its eventual changes was not a central issue for several reasons, especially the opposition between technical and conceptual work, prevailing in the discourse of innovation and research and also the underestimation of instrumental issues. Technology by itself was considered to foster changes in the teacher's role. This first trend gradually gave way to research that recognised and attempted to better understand the challenges that teachers face in the presence of digital technology (DT) and the need to rethink new possibilities for doing mathematics and addressing classroom management issues (Healy and Lagrange 2010).

In this chapter I will review from this latter perspective the trajectory of Michèle Artigue, showing how by directing doctoral theses, by conducting national innovative projects and by participating in projects crossing cultural and educational contexts, she played a substantial role in the research in this area. The following sections are not conceived as a continuous chronological path but rather as milestones based on episodes from Michèle's "long story with technology".[1]

7.2 From Students' Tasks to Teachers' Practices

In the early nineties, the French Ministry of Education asked a group of researchers headed by Artigue to work together with a group of expert teachers to identify the potential offered by a computer algebra system (CAS), DERIVE, for the teaching and learning of mathematics at secondary level (Abboud et al. 1995; Artigue 1997). The observations made during this collaboration clearly showed that integrating CAS into mathematics teaching was absolutely not a matter of simply adding a new artefact into a classroom. Indeed, the researchers asked the expert teachers to design lessons that they considered to be evidencing the power of CAS for mathematics learning. The teachers then provided lessons plans and their rationale as well as their expectations on how the lesson plans would take place in their classrooms (computer rooms). By observing these lessons, the research team shed light on the fact that the mathematical dynamics in the classroom within the lesson in progress resulted from a balance between two opposite tendencies. The first one favoured reflexive work, as expected by teachers. The second focused on productive

[1]The title of the chapter is inspired by a wording used by Artigue (2012, p. 25).

strategies, reducing thus the global coherence of students' activity. This was especially the case when students used what were named "fishing strategies": multiplying trials without spending time understanding computer feedback up to the moment something easily interpretable (in terms of the task's performing) happened. The research also found that the role of the teachers and their management of the lesson were essential for maintaining this adequate, but complex, balance. It was the didactic expertise of the teacher that prevented the second tendency (productive strategies) gaining precedence over the first one (reflexive work).

Broadly, this study showed that in addition to thinking out the affordances of digital technologies (DT) and the ways it affects mathematical learning, it became essential to investigate the role of the teacher within technology-mediated lessons. Simultaneously other researchers, in different contexts, came to the same conclusion. This was confirmed by a meta-analysis of over 600 international publications (published before 2000) on DT in the teaching and learning of mathematics (Lagrange et al. 2003). Starting from this period, the emphasis in many research studies began to shift toward aspects of teachers' practices when DT was integrated into their teaching, and on the complexity of this integration.

For instance, in the French sphere, Laborde and colleagues (Laborde 2001) highlighted that appropriation of DT by teachers was a long process. Reporting on teaching scenarios using dynamic geometry and their evolution over 3 years, Laborde stressed:

> We assume that really integrating technology into teaching takes time for teachers because it takes time for them to accept that learning might occur in computer-based situations without reference to a paper-and-pencil environment and to be able to create appropriate learning situations. But it also takes time for them to accept that they might lose part of their control over what students do (p. 311).

This is consistent with Ruthven et al. (2005), whose research tackling the use of dynamic geometry shows that teachers may constrain the potential of technology in order to retain control of the classroom. Indeed, teachers tend to reduce the exploratory dimension of DT in order to control students' explorations and to avoid students encountering situations that could obscure the underlying rule or could require explanations that go beyond the narrow scope of the lesson.

Adopting a more holistic perspective in understanding the key factors of teachers' activities and roles, Monaghan (2004) used Saxe's cultural model centred on emergent goals under the influence of four parameters. Using this model enabled Monaghan to locate critical influences on teachers' practice which he then used to explore the complexities of integrating technology into teaching. A central feature of this model was the notion of emergent goal that proved adequate to spot and interpret phenomena that frequently occur in technology based lessons, resulting of a gap between what the teacher was expecting and what really happened. Lagrange and Ozdemir (2009) also used this model to analyse episodes encountered by experienced teachers, marked by improvisation and uncertainty. By contrasting, in similar lessons, the classroom activity of two teachers (one positively disposed

towards the use of technology and the other not), they showed that suitable settings and favourable parameters did not guarantee less complexity in DT integration.

More generally, one can conclude from these examples and many others in education research that different approaches and frameworks were developed with the same purpose of better understanding the way teachers use technologies. Particular orientations can also be encountered that offer a wide range of theoretical and methodological constructs to examine teachers' use of technology in classrooms. A recent volume, "*The mathematics teacher in the digital era*", edited by Clark-Wilson et al. (2014), provides a more detailed and current overview of this domain.

Returning to the issue that opened this section, I point out that after the DERIVE project, a second project followed, also directed by Artigue, that studied the uses of symbolic calculators. The outcomes and theoretical work resulting from these two projects led Artigue and her colleagues to introduce a new and currently well-known framework, the Instrumental Approach (IA), which is presented and detailed in Chap. 6 (Kieran and Drijvers in this volume). It is worth noting that IA was first used as means of studying students' instrumental genesis; and a teacher perspective was afterwards introduced, that is, the notion of instrumental orchestration (Trouche 2004), also used by Drijvers et al. (2010).

7.3 Towards Geneses of Technology Uses

In 2003, Artigue and her colleagues was in charge of a regional French project involving more than 50 Grade 10 mathematics teachers (Artigue et al. 2007). The project aimed to study volunteer teachers' uses of web-based resources (Electronic-Exercise-Bases (EEB)) over a period of three years. The study was qualitative and the data was collected from lesson preparation plans, class observations, and responses to questionnaires and interviews. Most of these teachers were familiar with the use of technology in the classroom at the beginning of the project. The goal of the project was pragmatic in that it involved observing the potential of EEB in ordinary classes, with an emphasis on helping the weaker students (Abboud-Blanchard et al. 2007). The data analysis addressed the general questions: Why and how do teachers use EEB? What effect does this use have on their teaching activity? The outcomes emphasised the impact of using EEB in three phases of the teachers' activity: preparing lessons; interacting with students during a lesson; and reflecting after the lesson on a comparison between what was prepared and the effective activity of students. Outcomes mainly referred to teachers' wish to control the students' activity contrary to specificities of the EEB, and to teachers' focus on mathematical process in contrast with the EEB focus on answers only.

Data mining was also used in a subsequent national research project that explored the geneses of technology uses in different educational contexts: the

GUPTEN[2] project (Lagrange 2013). The aim of this project was to better understand how the practices of the teachers involved in the regional project evolved over time and the factors that shaped this evolution. Indeed, the GUPTEN project had a challenging perspective which was to identify the ordinary "uses" of DT that teachers developed, beyond the original perspective of innovation, and by searching for a state of equilibrium between paper-and-pencil traditional practices and the response to an external (institutional and social) demand to integrate DT into mathematics teaching and learning.

Multiple frameworks were used in this national project. The researchers attempted to combine the Instrumental Approach with a framework used in the French educational field to study teaching practices: the Double Approach (DA), with the Activity Theory as its frame of reference. The DA was introduced and developed by Robert and Rogalski (2005) to incorporate, on the one hand, a didactical perspective, which views the teachers' activities that involve task choices and classroom management as a key factor affecting students' activities, and on the other hand an ergonomic perspective, which considers teachers as professionals having craft knowledge, beliefs and previous experience whilst working in given institutional and social conditions. We also used the distinction between "productive" activity and "constructive" activity emphasized by cognitive ergonomists like Samurçay and Rabardel (2004). Indeed, by their actions, the subject (the teacher in this case) modifies the situation but also changes him or herself, i.e., develops his or her knowledge or builds new knowledge. The fact that the Instrumental approach and the DA could both be considered as expanding Activity Theory, by adding and articulating mathematics didactic perspective, ensured a certain a priori consistency and continuity on a meta-level within the national research study.

The main contribution of this work was to provide a theoretical construct which could be used to grapple with the complexity of the emergence and evolution of teachers' practices in technology-based lessons. This theoretical construct was a thoughtful way of modelling geneses of technology uses (for more details, see Abboud-Blanchard and Lagrange 2006, Abboud-Blanchard and Vandebrouck 2012). It focused on the development of technology uses by teachers. Considering the processes of instrumental genesis of specific artefacts by the teacher, the notion of geneses of uses transcends these processes by taking into account the globality and stability of the teacher's practices (with and without DT). The geneses of uses are considered as patterns of development in three levels of practice' organisation, related both to temporality and to goals in the teaching activity: the micro level of "automatisms" and elementary gestures; the local level related to management issues and to teacher-students interactions; and the global level referring to preparations and scenarios.

As explained at the end of the above section, the notion of instrumental genesis was introduced and developed in research into mathematics education by Michèle Artigue and her colleagues. They also drew from the Anthropological Theory of

[2]Genèses d'Usages Professionnels des Technologies Numériques chez les Enseignants.

Didactics (ATD), highlighting the role of instrumented techniques and of their interaction with paper-and-pencil techniques, and introducing the twofold characteristics of techniques-"pragmatic" and "epistemic"-that Rabardel already identified for instrumental schemes.

As to the recent development that the GUPTEN project proposes, it broadly draws on the development of the instrumental approach by Rabardel and colleagues. Indeed, artefacts are considered not as isolated but as inscribed into systems of artefacts; the subjects' activity often implies the use of multiple instruments (Rabardel and Bourmaud 2005).

Relative to the two main conceptual frameworks inspiring these developments, Lagrange (2012) recently attempted to evaluate the contribution of ATD and of activity theory (and so to the ensuing IA and DA) in view of overarching issues related to the use of DT by mathematics teachers. He emphasised that, although very different in their nature and roots, the two theories *start from a common vision of knowledge as the product of human activity in social and cultural contexts* (p. 33). He then demonstrated how, in a specific research study, the use of the two frameworks was possible and insightful.

These diverse efforts that aim to compare, connect and integrate theoretical frames are in accordance with Michèle Artigue's current preoccupations about the networking of theories (see for example Artigue and Mariotti 2014). This trend in Michèle's research is further developed in Chap. 6 (Kieran and Drijvers in this volume) and Chap. 3 (Kidron et al. in this volume).

7.4 Improving Teacher Education

In the proceedings from a Conference on ICT in school mathematics, Artigue (1998) entitled her paper: "*Teacher training as a key issue for the integration of computer technologies*". The paper was her first published overview of obstacles to the integration of ICT; she claimed that *the poor sensitivity* of teacher training to these obstacles partly explains *its poor efficiency*. Indeed, research projects in which she was involved and doctoral thesis that she was directing (see for example Abboud 1994) brought her to highlight the fact that a current tendency, at the time, in teacher training was to consider that disturbances due to the presence of technologies can be avoided by *careful preparation and proper choice* of a situation's variables relative to students' tasks. In the closing section of the text, she states:

> Teacher training based on innovative values and militancy has shown evident limits. For the reasons mentioned above, our personal conviction is that such resistant obstacles will not be overcome without giving didactic analysis a more important role in teacher training and without providing teachers with didactic tools allowing them to analyse transpositive processes, to identify the didactic variables of situations and pilot them, analyse their professional techniques and the way these are modified by the use of computer technologies (p. 127).

Several years later, in a text synthesising her current research, Artigue once more attempted to identify and analyse the difficulties and challenges in technology integration (Artigue 2004). She ended her discussion with the following statement:

> Training has not been able up to now, to go beyond the primitive phase of pioneer militancy that is associated to the entrance of any kind of newness in the educational system. This fact leads to a general underestimation of the necessary changes in the professional work of the teacher, of the mathematical, technological and didactic expertise required if one wants to have computer technologies really benefits mathematics teaching and learning (p. 221).

She also emphasised that educational policies continued to overlook how DT participates in *destabilising established routines* and increasing the complexity of teaching activity. She added that necessary changes must be supported by insightful knowledge and appropriate training.

This situation described by Michèle has gradually become a major concern of current research. Most teacher education researchers are themselves teacher educators studying the teachers with whom they work. Some others are focusing on the kinds of knowledge developed in teacher training courses and on training strategies used by teachers' educators (Abboud-Blanchard 2013; Emprin 2007). In the 17th ICMI Study (Hoyles and Lagrange 2010), several papers analysed views and options of teacher education courses in mathematics and technology. They offered features by which teacher education courses might be characterised, especially those of changes in teachers' role, activity and practices. In their text, Grugeon et al. (2010) describe a number of teacher development courses implanted in different cultural and educational contexts. Even if each course had its own consistency, the authors tried to determine the underlying options and hypotheses; a categorisation model according to the content and the teaching strategies followed. Six types of course content were identified: the potential of software for learning, the evolution of curriculum due to technology use, instrumental genesis, the reworking of old tasks and the creation of new tasks for use with technology, appropriate new teaching abilities, and working with technology in various professional contexts. Four main strategies were also identified: demonstration (showing how to), role playing (teacher as student), 'in practice' (teacher as reflective practitioner), and learning communities. It is interesting to note that the first strategy, demonstrating good practices, was the only one common to all five courses. The authors hoped through this classification to provide useful support for future work in analysing and describing teacher education projects. Reflecting on the latter, Artigue (2010) declared in her closing chapter:

> But we find also in the different contributions some evidence that we are now ready to enter a new phase, and that the Study can efficiently contribute to this new phase through the analysis it provides of current practices and of their resulting effects, through the methodological and conceptual tools it proposes, through the positive and substantial examples it presents of teacher preparation and professional development programs. These examples moreover show that the technology itself offers now new and powerful tools for supporting and accompanying the professional development of teachers in that area, seen as a collective and collaborative enterprise […] (p. 471)

Shifting into a 'higher level', new educational studies have emerged that tackle the topic of educating the educators.[3] New approaches focus on the need for a much closer coordination between research, development, design, and practice, and acknowledge the impact that educating teacher educators has on improving teacher education itself, which has, in turn, repercussions for a wider implantation of technology in everyday teaching practices. Still, to be efficient, this implies long-term projects and innovative design of teacher education courses (Abboud-Blanchard and Robert 2013). This cannot, though, be the task of individuals, neither left in the sole hands of researchers (Artigue 2009). Instead, it requires specific structures able to organise and evaluate the effects of such approaches on teacher educators' professional development.

All of the previous issues and results were discussed within the session dedicated to this topic[4] in the International Conference "Hommage à Michèle Artigue" (in Paris 2012). But at the same time, open questions emerged such as: What main criteria are needed, and must be displayed, in teacher education to help teachers efficiently organise technology-based sequences? How can questioning the balance between pragmatic and epistemic values of technology (Artigue 2002) be integrated in pre-service and in-service teacher education? How do we adapt current teacher education to new generations of "plugged in and connected" teachers? Following on from this last question, Artigue points out that we are living in a new digital era and are witnessing the arrival and spread of new artefacts which shape our personal and professional lives, including smartphones, touch-sensitive screens, mathematical applets, and diverse mobile technology devices. She also stresses the important role that social networks play in communication modes (Artigue 2013). She deduces that traditional paths in teacher education must be improved especially by further reflecting on the potentialities of e-learning and on the growth of new ways of teaching such as the Massive Online Open Courses (MOOC).

To summarise, I illustrated throughout this section how the discourse of Artigue on teacher education kept coherence and even a certain recurrence over the passage of time. By synthesising issues and outcomes from national and international research, I pointed out that teacher education remains a key factor for any possible evolution of DT integration in educational systems. It surely illustrates how difficult these issues are to deal with and that the research community has to develop new directions to challenge visions related to teachers' professional development and to expand this research area.

[3]See for example the Conference on international approaches to scaling up professional development in maths and science education, December 2014 in Essen, Germany.

[4]This session was coordinated together with Colette Laborde; special thanks to her.

7.5 Concluding Comments

Throughout this chapter I have attempted to revisit Michèle Artigue's work on the teacher's perspective in technology-based education. I used episodes from her research work to show how she contributed, often in a collaborative way, to introduce new guidelines and new perspectives for research in this field. Nevertheless it is also a fine-grain analysis based on her work within diverse research projects, which led Artigue to provide reliable insights into the complex issue of integrating technologies into educational systems.

I would like to add that Michèle had, and still has, a role of actor beyond her research activity, often positioned at an institutional level; intervening and working to improve mathematics teaching and learning in technology environments. One could say that she is playing a dual role, by creating efficient conceptual frames and methodological tools, and at the same time working in close collaboration with actors. For instance, she regularly designed and intervened in teacher education courses proposed by the Institute of Research in Mathematics Education (IREM) that she headed for several years and still is an active member of the board. She also continued to work with secondary teachers to experiment with innovation, to produce educational resources, and to participate in projects addressing professional development. Indeed, to accompany the slow evolution of incorporating technology into school mathematics, researchers have to take into account a vision close to what teachers experience in their everyday professional lives.

Finally, I would like to quote Michèle from a recent plenary conference entitled: *Teacher education and technology: a major challenge*[5]:

> […] to teach math in this digital era, it is not only to learn to integrate in teaching practices technologies such as calculators, dynamic geometry, spreadsheets or computer algebra systems (CAS) which have long been the emblem of this integration, and this even if the effective integration of these 'old' technology is still marginal. It is learning to take advantage of many resources provided by the digital world for teaching and learning, and new modes of social interaction and communication that it promotes. […] More than ever, the need to thorough studies of teachers' professional development related to digital technologies is topical; the need for a better understanding of teaching practices in technological environments, of their determinants, and of their evolution dynamics. (Artigue 2013, pp. 5–6, our translation)

Indeed, this is another challenge for all educational researchers to continue towards new directions and perspectives in a journey that is still unfinished…

[5]The original French title is: La formation technologique des enseignants: un défi majeur.

References

Abboud, M. (1994). *The integration of computers in mathematics education: Symptoms of a dysfunction*. PhD thesis, University of Paris 7, France.

Abboud, M., Artigue, M., Drouhard, J. P., & Lagrange, J. B. (1995) *Une recherche sur le logiciel DERIVE*. Cahier Didirem spécial n°3. Eds. IREM de Paris7.

Abboud-Blanchard, M. (2013). *Technology in mathematics education. Study of teachers' practices and teacher education. Syntheses and new perspectives.* Synthesis document for the habilitation to supervise research. Universty of Paris Diderot.

Abboud-Blanchard, M., Cazes, C., & Vandebrouck, F. (2007). Teachers' activity in exercices-based lessons. Some case studies. In D. Pitta-Pantazi & G. Philippou (Eds.), *Proceedings of the Fifth Congress of the European Society for Research in Mathematics Education, Larnaca, Cyprus (*pp. 1827–1836).

Abboud-Blanchard, M., & Lagrange, J. B. (2006). Uses of ICT by pre-service teachers: Towards a professional instrumentation? *The International Journal for Technology in Mathematics Education, 13*(4), 183–191.

Abboud-Blanchard, M., & Robert, A. (2013). Strategies for training Mathematics teachers. The first step: Training the trainers. In F. Vandebrouck (Ed.), *Mathematics classrooms: Students' activities and teachers' practices* (pp. 229–245). The Netherlands: Sense Publishers.

Abboud-Blanchard, M., & Vandebrouck, F. (2012). Analysing teachers' practices in technology environments from an Activity Theoretical approach. *The International Journal for Technology in Mathematics Education, 19*(4), 159–164.

Artigue, M. (1997). Le logiciel DERIVE comme révélateur de phénomènes didactiques liés à l'utilisation d'environnements informatiques pour l'apprentissage. *Educational Studies in Mathematics, no, 33*, 133–169.

Artigue, M. (1998). Teacher training as a key issue for the integration of computer technologies. In D. Tinsley & D. C. Johnson (Eds.), *Information and communication technologies in school mathematics* (pp. 121–130). London: Chapman & Hall.

Artigue, M. (2002). Learning mathematics in a CAS environment: The genesis of a reflection about instrumentation and the dialectics between technical and conceptual work. *International Journal of Computers for Mathematical Learning, 7*, 245–274.

Artigue, M. (2004). The integration of computers technology in secondary mathematics education. In J. Wang & B. Xu (Eds.), *Trends and challenges in mathematics education* (pp. 209–222). Shanghai: East China Normal University Press.

Artigue, M. (2009). Didactical design in mathematics education. In C. Winslow (Ed.), *Nordic reserarch in mathematics education* (pp. 7–16). Denmark: Sense Publishers.

Artigue, M. (2010). The future of teaching and learning mathematics with digital technologies. In C. Hoyles & J. B. Lagrange (Eds.)*, Digital technologies and math education. Rethinking the terrain. The 17th ICMI Study* (pp. 463–475). New York: Springer.

Artigue, M. (Ed.). (2011). *Les défis de l'enseignement des mathématiques dans l'éducation de base*. Paris: UNESCO.

Artigue, M. (2012). Mathematics education as a multicultural field of research and practice: Outcomes and challenges. In J. Dindyal, L. P. Cheng, & S. F. Ng (Eds.), *Mathematics education: Expanding horizons. 2012 Proceedings of Conference of Mathematics Education Group of Australasia*. http://www.merga.net.au/documents/Artigue_2012_MERGA_35.pdf. Accessed February 22, 2015.

Artigue, M. (2013). La formation technologique des enseignants un défi majeur. In *Proceedings of the San Domingo Congress ICEMACYC*. http://www.centroedumatematica.com/memoriasicemacyc/Conferencia_plenaria,_Artigue.pdf. Accessed February 22, 2015.

Artigue, M., Abboud-Blanchard, M., Cazes, C., & Vandebrouck, F. (2007). *Suivi de l'expérimentation de la région Ile de France : ressources en ligne pour l'enseignement des mathématiques en classe de seconde.* Rapport final. IREM de Paris 7.

Artigue, M., & Mariotti, M. A. (2014). Networking theoretical frames: The ReMath enterprise. *Educational Studies in Mathematics, 85*, 329–355.

Clark-Wilson, A., Robutti, O., & Sinclair, N. (Eds.). (2014). *The mathematics teacher in the digital era: An international perspective on technology focused professional development*. London: Springer.

Cornu, B., & Ralston, A. (Ed.). (1992). *The influence of computers and informatics on mathematics and its teaching*. Science and Technology Education. Document Series 44. Paris: UNESCO.

Drijvers, P., Doorman, M., Boon, P., Reed, H., & Gravemeijer, K. (2010). The teacher and the tool: Instrumental orchestrations in the technology-rich mathematics classroom. *Educational Studies in Mathematics, 75*, 213–234.

Emprin, F, (2007). *Formation initiale et continue pour l'enseignement des mathématiques avec les TICE: cadre d'analyse des formations et ingénierie didactique*. Thèse de didactique des disciplines. Université Denis Diderot.

Grugeon, B., Lagrange, J. B., Jarvis, D., et al. (2010). Teacher education courses in mathematics and technology; analyzing views and options. In C. Hoyles & J. B. Lagrange (Eds.) *Digital technologies and math education. Rethinking the terrain. The 17th ICMI Study* (pp. 329–345). New York: Springer.

Healy, L., & Lagrange, J. B. (2010). Introduction of chapter 12: Teachers and technology. In C, Hoyles & J. B. Lagrange (Eds.) *Digital technologies and math education. Rethinking the terrain. The 17th ICMI Study* (pp. 287–292). New York: Springer.

Hoyles, C., & Lagrange, J. B. (Eds.). (2010). *Digital technologies and Math Education. Rethinking the terrain. The 17th ICMI Study*. New York: Springer.

Laborde, C. (2001). Integration of technology in the design of geometry tasks with Cabri-geometry. *IJCML, 6*, 283–317.

Lagrange, J. B. (2012). Anthropological approach and activity theory: Culture, communities and institutions. *The International Journal for Technology in Mathematics Education, 20*(1), 33–37.

Lagrange, J. B. (Dir.). (2013). *Les technologies numériques pour l'enseignement: usages et genèses*. Toulouse: Octarès.

Lagrange, J. B., Artigue, M., Laborde, C., & Trouche, L. (2003). Technology and math education: A multidimensional overview of recent research and innovation. In J. Bishop, K. Clements, C. Keitel, J. Kilpatrick, & F. Leung (Eds.), *Second international handbook of mathematics education* (pp. 237–270). Dordrecht, The Netherlands: Kluwer.

Lagrange, J. B., & Ozdemir, E. (2009). Teacher's emergent goals in spreadsheet based lessons: Analysing the complexity of technology integration. *Educational Studies in Mathematics, 71* (1), 65–84.

Monaghan, J. (2004). Teachers' activities in technology-based mathematics lessons. *The International Journal of computers for mathematical learning, 9*, 327–357.

Rabardel, P., & Bourmaud, G. (2005). *Instruments et systèmes d'instruments.* In P. Rabardel & P. Pastré (Eds.), Modèles du sujet pour la conception. Dialectiques activités développement (pp. 211–229). Toulouse: Octarès.

Robert, A., & Rogalski, J. (2005). A cross-analysis of the mathematics teacher's activity. An example in a French 10th grade class. *Educational Studies in Mathematics, 59*, 269–298.

Ruthven, K., Hennessy, S., & Deaney, R. (2005). Incorporating dynamic geometry systems into secondary mathematics education: Didactical perspectives and practices of teachers. *Moving on with dynamic geometry* (pp. 138–158). London, UK: Association of Mathematics Teachers.

Samurçay, R., & Rabardel, P. (2004) Modèles pour l'analyse de l'activité et des compétences: propositions. In R. Samurcay et P. Pastré (Eds.), *Recherches en Didactique Professionnelle*. Toulouse: Octarès.

Trouche, L. (2004). Managing the complexity of human/machine interactions in computerized learning environments: Guiding students' command process through instrumental orchestrations. *International Journal of Computers for Mathematical Learning, 9*, 281–307.