Some conclusions from a review of French research reports about the integration of calculators in mathematics teaching

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The questions below are taken from an American-led review by G. Burill (2002)[1]. They are applied here to a review of a set of French research papers published between 2002 and 2008[2].

Question 1. *How do teachers use handheld graphing technology and how is this use related to their knowledge and beliefs about technology, mathematics, and teaching mathematics? What do teachers know and believe about handheld graphing technology and how is this related to their beliefs about mathematics and mathematics education?*

French research indicates that the integration of calculators in teaching met, at the beginning, with resistance from teachers. The research identifies two possible causes for this resistance: the complexity of this integration, and fears generated among some teachers that the technology might affect their status. Over time, teachers have discovered the potential of these tools to support a different level of reasoning by the students, promoting the development of mathematics understanding which includes a more experimental approach: exploration, or conjecture to arrive at the evidence. Difficulties remain for students when articulating work with paper / pencil and calculator, when articulating exploration, conjecture and proof, and for the teacher when scaffolding these connections. The integration of calculators at the same time requires and fosters a new perspective by teachers on their teaching of math: less formal and more experimental.

With regard to the preparation of courses, research shows the emergence of a more collective pattern of work by teachers, including the use of databases of online resources, and pooling under certain conditions resources they propose. From this viewpoint, one can also say that the integration of calculators assumes and promotes changing the patterns of work of teachers.

These effects are the subject of various studies of teacher training (training that is, or that should be done). Studies of the beliefs and conceptions of teachers of mathematics and their evolution are still rare and should be planned for the future. We can detect, in the French research, a strong interaction between three poles: the technological evolution, the evolution of the needs and expectations of teachers, and the changing goals of educational research.

Question 2*. With what kinds of mathematical tasks do students choose to use handheld graphing technology? How do students use the technology to carry out these tasks?*

Most French research has examined such issues for a long time (longer than questions about the role of teacher). Over time, calculators have evolved, as has the nature of work allocated to the calculator (including type of calculation, or type of validation of the results) as well as the very nature of working with this tool, which is becoming more experimental.

The autonomy of students' activity evidently depends on the degree of ownership of the technology used and the skills of the students. It also depends strongly on the kind of tasks assigned by the teacher to students and assistance provided for construction of calculator-based techniques in the classroom: in general, we can say that students widely use calculators, even complex ones, only for simple tasks, but that use of a wide range of functionality of the tool, and the inclusion of this tool in a rational process of exploration, conjecture and evidence, are largely dependent on the involvement of the teacher in scaffolding this integration in the classroom.

It may be necessary to conduct research to develop better understanding of the continuity of learning, and of involvement in an experimental approach to the acquisition of the concepts used by the teacher.

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[1] Burill G. (dir.), Allison J., Breaux G., Kastberg S., Leatham K., Sanchez W. (2002), *Handheld Graphing Technology in Secondary Mathematics: Research Findings and Implications for Classroom Practice*, Dallas, TX: Texas Instruments, U.S.A.

[2] For the complete view, see Sabra H., Trouche L. (ed.), (2008), *Revue d'articles francophones sur l'intégration des calculatrices dans des mathématiques*, 2002-2008, INRP.

Question 3*.* *What mathematical knowledge and skills are learned by students who use handheld graphing technology? In what ways do students use this knowledge and these skills?*

Most French studies reveal active participation of students and good engagement in the mathematical work requiring the use of calculators. An accompanying need for the teacher to support the work of students in mathematics, or with technological difficulties, nevertheless seems necessary: this involves designing specific activities, and arranging in class for appropriate forms of assistance (for example technical reference sheets to support use of the tool).

Through the use of calculators, students handle most mathematical objects, and they have a greater variety of ways to accomplish the same purpose. This can be, for them, a rich experience, or it can be a source of additional complexity which makes it difficult to develop a stable knowledge structure.

Mathematics knowledge is highly related to the environment in which it was built: thus graphing calculator environments tend to promote assimilation between a function and its graphical representations, while symbolic calculator environments tend to favor, within the limits of a function, more a point of view resulting from the calculation process.

Few studies, to date, focus on the mathematical techniques instrumentally built by the students: their diversity, their stability, their effectiveness and institutional recognition. The establishment of a practical test for the baccalaureate in France could change this research focus.

Question 4. *What is gained mathematically by students using handheld technology that cannot be observed in a non-technology environment? In what ways do students use this knowledge and these skills?*

Most French studies emphasize what is considered an essential benefit of graphing calculators: to be able to adjust easily to different modes of representation (numerical, graphic, symbolic and geometrical). This advantage is essential to learning, because mathematical concepts can be built only through a variety of representations that allow students to separate the abstract meaning of a concept from any of its representations. The research points out, from this point of view, the significance of technological advances such as sharing a screen between multiple applications, or communication among several calculators and a common screen (in *TI-Navigator*).

Articles studying detailed processes implemented in the classroom note, however, that technological advantages are not exploited spontaneously by students (for example, it is quite natural for a student to stay in the graphical application and navigate with single command to zoom). Taking advantage of multiple representations requires scaffolding by the teacher, to guide the complex conceptual and operational processes of transition from one representation to another.

Question 5. *What impact does handheld graphing technology have on the performance of students from the different gender, racial, socio-economic status, and achievement groups?*

The French studies on calculators do not take into account gender or ethnicity. Socio-economic status (SES) issues are taken into account only marginally. SES appears strongly, however, with questions of how to equip schools and students. The cost of equipment represents an obstacle. In that sense, as studies show that necessary costs of technological equipment for students, just like textbooks, should be taken into account, where socially necessary, by institutes or local authorities.

It appears clear, however, that the development of collaborative work groups among students is strongly linked to the development of technological environments allowing networking. This asks in a new way, the question of continuity of school (work in the classroom and outside class).